IBA
TECHNICAL
REVIEW

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Measurement and Control

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Foreword

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The recent change by which the Independent Television Authority has become the Independent Broadcasting Authority reflects well the growing responsibilities of its engineering side. The success of building up a duplicated UHF television network already reaching 17 out of every 20 people in the United Kingdom is self evident. Equally encouraging has been the high standard of colour television which has come from the many modern studio complexes set up by the Independent Television programme companies; a standard which compares favourably with – and competes successfully with – that achieved elsewhere.

Today the broadcast engineer is a highly specialized and highly committed individual. Only a tiny fraction of what he does, what he thinks, what he plans is likely to be visible to the public concerned only with the programmes that appear on the box.

For this reason the need for broadcast engineers to communicate with others in their own field is vitally important. Yet the first reaction of almost any engineer is to feel that he is subject already to too great a flood of printed matter. Words and journals and circulars and catalogues pour into his in-tray, and thence – often unread – into his waste paper basket. Many he rejects because they are not written for him by those who are like him.

Yet he has a real and urgent need for information on what is still a constantly changing scene: automation, computers in broadcasting, digital electronics, large-scale integration are all questions which will affect his working life in the next decade. Selected papers, written by those actively engaged in the work they describe, are still a vital commodity.

This new series of occasional papers, grouped under the all-embracing title of *IBA Technical Review*, has thus been designed to permit the fullest flexibility. Some issues will be devoted to a single subject; some to topics only loosely connected; others to the collation of data required constantly as a source book.

The aim is thus to present papers and information that have a significant bearing on the work of the broadcasting engineer today and tomorrow: to collect together, in permanent record, papers germinated within Independent Broadcasting, reflecting the views and trends of this work, and to present them in a form which will, I hope, be of lasting value and interest to readers.

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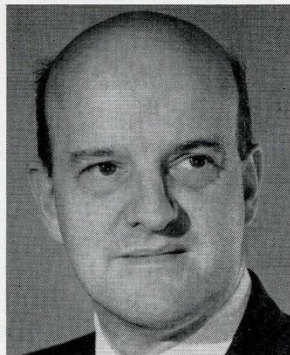
Some Methods of Automatic Analysis of Television Test Signals

by R H Vivian

Synopsis

Investigations have been made into methods of digitally analysing television test signals to be used in a prototype automatic monitoring equipment. To allow, wherever possible, maximum compatibility with existing manual methods, the already established insertion test signals (ITS) were employed. A preliminary survey confirmed that the component waveforms of ITS were generally amenable to digital analysis, although in some cases the approach would have to be quite different from that adopted for manual assessment. The effects of noise had to be taken into account. Suitable methods were found to be available for analysing insertion test signals by means of an on-line digital computer to obtain the relevant transmission quality parameters.

During the first 17 years since its establishment in 1954 the Independent Broadcasting Authority (until July 1972 entitled the Independent Television Authority) brought into service 47 VHF transmitting stations using the 405-line black-and-white standard and providing a service to 98·7% of the population of the United Kingdom. This programme of construction is illustrated in Fig.1. Before it was completed in 1970 a duplicated service using the 625-line PAL colour system in UHF had already commenced from the first 12 of what will eventually be an entirely new complex of transmitting stations. It is intended that when this UHF service has been firmly established throughout the country the VHF service will close down, but it is first necessary to provide a national coverage in UHF approaching the present VHF level and to achieve this it is expected that some 55 main and 440 relay stations will be required. Naturally a building programme of this magnitude must be spread over many years and until this has largely been completed, and to allow single-standard VHF receivers currently in use to have a reasonable period of life, it was decided that the two services should run concurrently. The programme material is the same in each case though of course viewers in UHF are offered the advantages of 625 lines
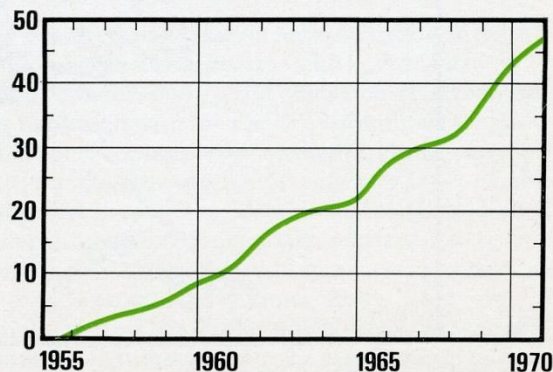
Fig.1. The increase in the number of the IBA'S VHF television transmitting stations 1955–70. In all, 47 were commissioned giving coverage to 98·7% of the population.
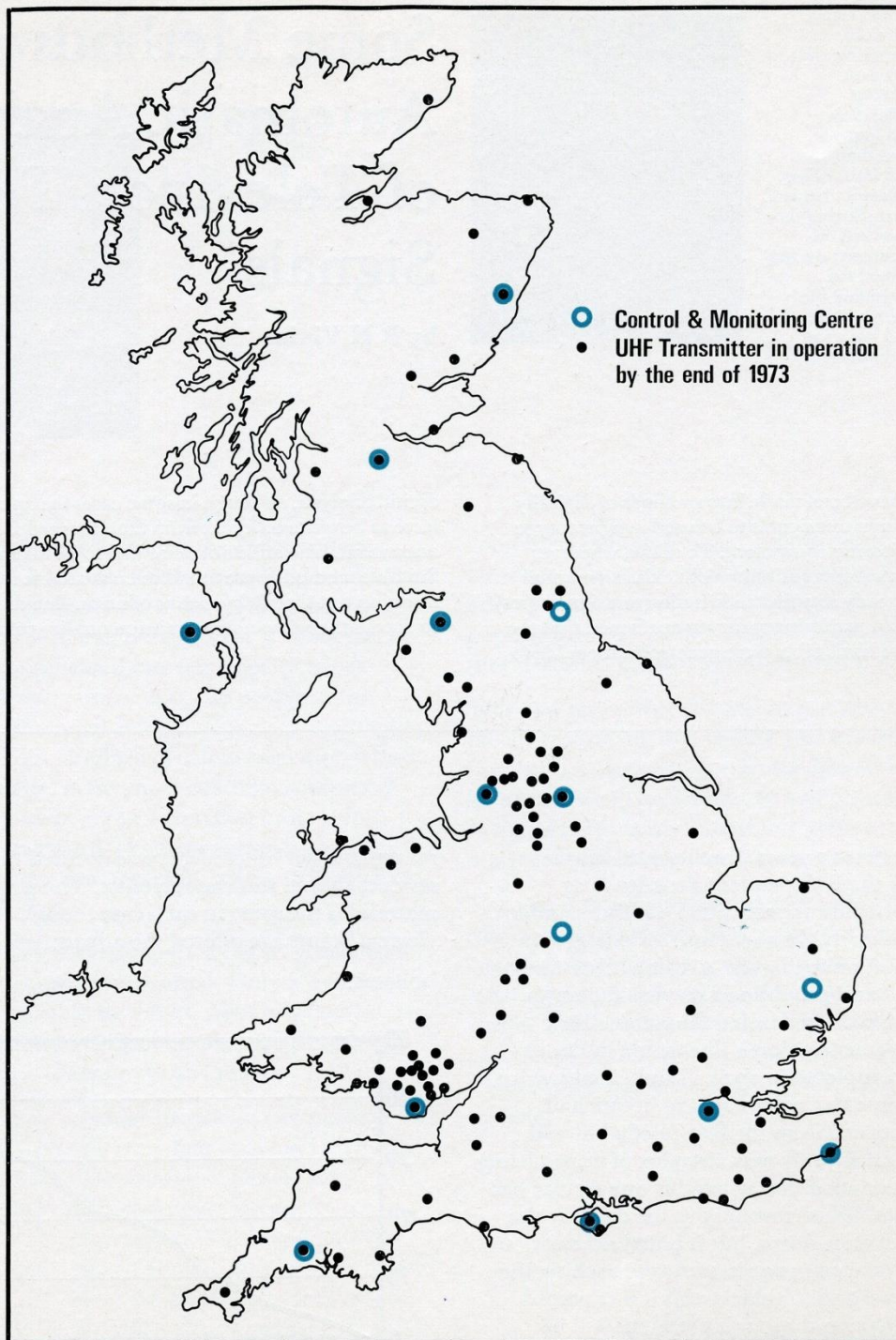
Fig.2. The Independent Broadcasting Authority owns and operates VHF and UHF transmitters throughout the United Kingdom. UHF transmitters are unattended, even where they share a site with an attended VHF station. Monitoring and control of the UHF transmitters is concentrated at the centres marked with a coloured circle. The black dots show those UHF transmitters which will be in operation by the end of 1973.

and colour. By the end of 1973, 117 of the UHF stations are planned to be in operation, see Fig.2.

One of the biggest problems confronting the IBA in contemplating a task on such a scale as this was, and still is, the monitoring and control of its output without incurring an appreciable increase in staff. A system of automation seemed to be called for and so, based on experience gained from the 28 VHF transmitters which are unattended, it was decided at the outset that *all* the UHF transmitters should be unattended right from the time they first enter service.

The federated regional structure of the Independent Television network, which is the most extensively equipped colour broadcasting operation in Europe, comprises 15 separate programme companies in 14 areas (London has two, one for weekdays and one for weekends) and a separate news service for national and international news owned jointly by the programme companies. With so many originating sources distributed throughout the country, the IBA rents 39 inter-city trunk circuits with over 5 500 miles of vision links and rebroadcast links. The precise configuration of this network is changed many times each day.

The operations staff responsible for all the IBA's UHF transmitters is being concentrated at 14 Control and Monitoring Centres spaced roughly one to each of the 14 programme company regions. These control centres are also indicated in Fig.2. At the moment, picture quality is monitored subjectively but this will become increasingly difficult as the number of transmitters to be controlled at some monitoring centres increases to 30 or more. At the same time the cost of subjective monitoring becomes greater, particularly as the number of hours of broadcasting increases. The allocation of frequencies in the United Kingdom makes provision for four television networks. At the moment only three programme channels are utilized but if the fourth is made available to the IBA then the expense and complexity of picture quality monitoring by traditional methods becomes prohibitive. These factors prompted us to investigate the use of a digital computer to monitor the transmission quality of television signals.[1]

There are two distinct monitoring situations. The first is when monitoring from line. In this case the signal is fairly noise-free and the amount of noise measured in the signal is reasonably representative of that received by viewers in the main service area. In the second situation the signal to be monitored is received off-air from a distant relay transmitter. If the Control and Monitoring Centre is outside the service area of the relay transmitter it is then necessary to be able to measure the signal parameters despite the presence of an abnormally large amount of noise. Both cases have been included in a series of investigations into methods of digitally analysing television test signals with the object of providing the basis for signal measurement computer programs to be used in a prototype automatic monitoring equipment for PAL colour transmissions.

To allow maximum compatibility with existing methods of measurement it was decided to employ, wherever possible, the already established insertion test signals (ITS). A preliminary survey confirmed that the component waveforms of the insertion test signals were amenable to digital analysis although in some cases the approach would have to be different from that adopted for manual assessment. Figure 3 shows the international vertical interval test signals used in the United Kingdom.

Analogue to digital conversion

If computation is to proceed digitally then there is a basic requirement for a device which will sample and digitize the incoming analogue test signal with adequate speed and accuracy. The well known sampling theorem, formalized by Shannon,[2] indicated that for the UK video bandwidth of 5·5 MHz the sampling rate should not be less than 11 MHz. Preliminary studies showed that it would be advantageous to the measurement of the chrominance parameters if the sampling rate were raised to approximately 13 MHz, that is to say, to the third harmonic of the UK colour subcarrier frequency $(3 \times 4 \cdot 433\,618\,75 \text{ MHz})$.

The effects of quantization noise on the digitized signal suggested a target resolution of ten bits (approximately 0·1%), but no device which combines this resolution with the required sampling rate has yet become commercially available. However, an eight-bit analogue-to-digital converter (ADC) capable of meeting the rate specification had been developed in the United Kingdom under a joint IBA/BBC research agreement. An eight-bit resolution corresponds to an amplitude error of 0·4%. Since the 13 MHz sampling rate is too fast for direct input to the digital computer an integrated-circuit intermediate buffer store is used. This store will hold up to 128 eight-bit word samples of an insertion test signal occurring during the field blanking time for transfer to the

TEST LINE — LUMINANCE ONLY

U.K. INSERTION TEST SIGNAL A SYSTEM I — LINES 19 & 332
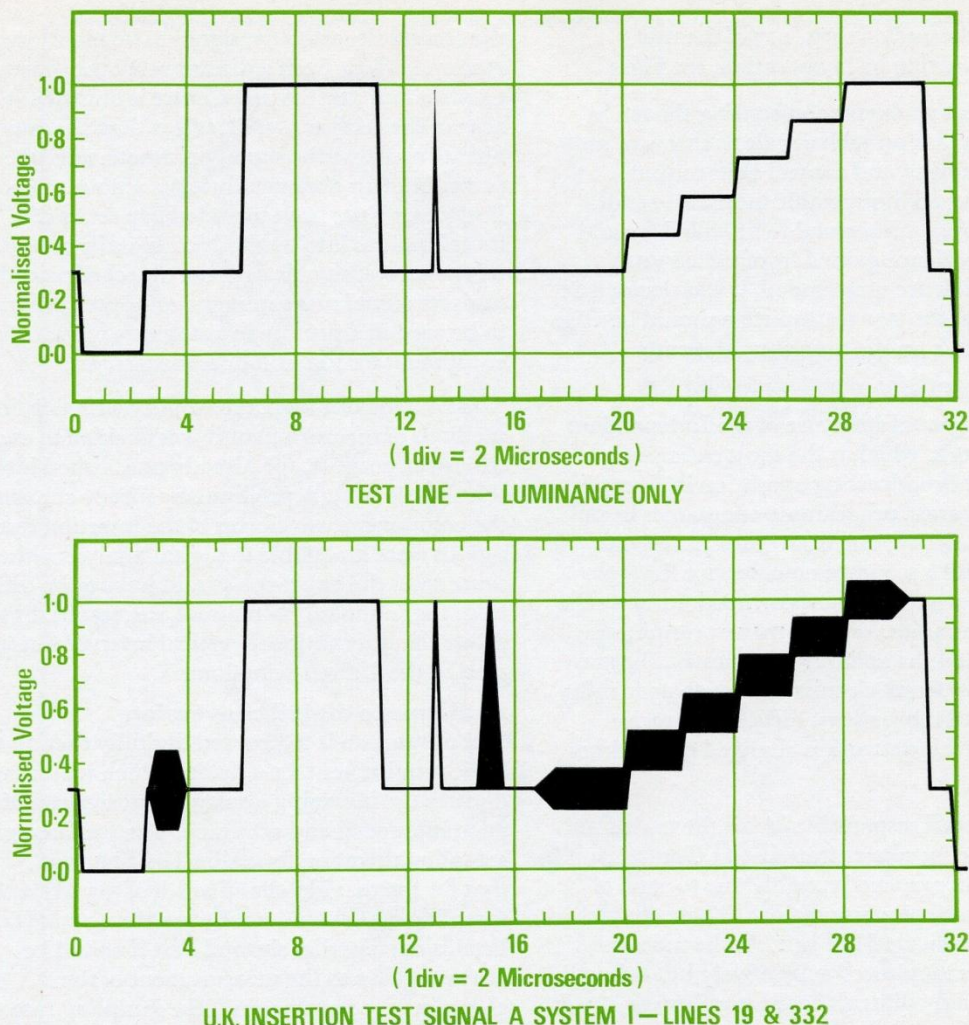
Fig.3. The Interval Test Signals (ITS) illustrated here are the internationally agreed waveforms used by the IBA for monitoring the performance of its network, and are distributed with all programmes. It is these waveforms which are automatically analysed by the methods described in this paper.

computer during the subsequent 20 ms picture field. In order to analyse all the required features of the waveforms it is also necessary, under instructions from the computer, to vary the time period of the train of samples relative to the waveform under test.

Measurement of K-rating

Normally, for monochrome monitoring at least, subjective assessment of overall picture quality is closely related to the worst of the K-ratings obtained from measurement of the 2T sine-squared pulse and bar waveforms, [3, 4, 5] even though such waveforms do not cover all picture quality parameters. It was therefore decided to adopt the accepted K-ratings as the measure of linear waveform distortion.

Although automatic determination by analogue means involves some difficulties such as storage during signal averaging processes, the use of a digital computer overcomes most of the problems. A digital method which has shown some experimental success provides the first illustration of the programming techniques developed for ITS analysis.[6] Figure 4A represents a distorted 2T pulse which is sampled at 75 ns intervals, the sample points being indicated by the small circles. In other contexts, time-series methods could be employed to obtain K-ratings directly from such samples[7] but these methods have been purposely avoided in the interests of better compatibility with the current manual methods. The program uses an algorithm representing the
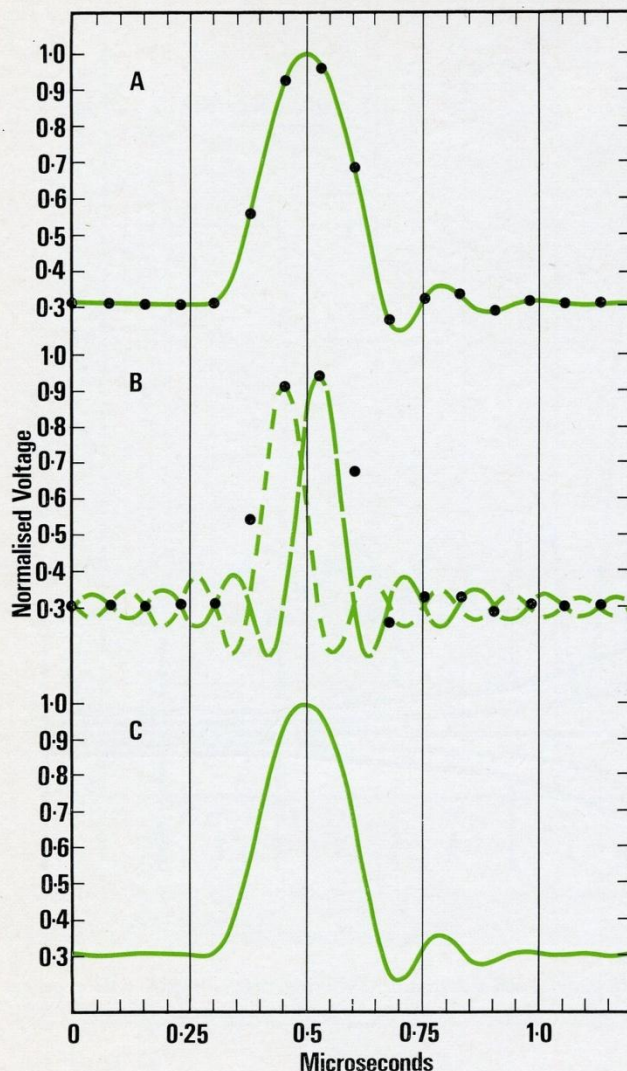
Fig.4. The incoming, distorted, analogue test waveform shown at (A) is sampled at the times indicated by the black dots. In reconstructing the analogue waveform from the digitized samples, an interpolation technique is used and each sample is replaced by a function of the general form of Fig.6. In (B) above, the two highest sample points only have been replaced by their interpolations functions in order to illustrate the reconstruction technique. Each waveform has a peak value corresponding to its own sample value but has zero amplitude at times corresponding to all the other sampling points. Addition of all the interpolation functions gives the curve of (C) above, which passes through all the sample points.

standard graticule (Fig.5) employed for manual K-rating measurements and hence makes it necessary to introduce a reconstruction mechanism by means of which a number of accurately interpolated points are

interposed between the original samples. Processes equivalent to joining the comparatively widely spaced sample points by straight lines have proved totally inadequate and quadratic interpolation methods have not shown much promise either. After several such attemps at computer reconstruction of the waveform recourse was made to the function

$$F_n(t) = A_n \frac{sin(\omega t + \phi_n)}{wt + \phi_n}$$

where A_n is the sample amplitude
$\quad\quad n$ is the number of samples
$\quad\quad \pi/\omega$ is the sampling interval
and $\quad \phi_n$ is the phase constant introduced to centre the waveform on the sample.

The function $[sin(\omega t + \phi_n)]/(\omega t + \phi_n)$ possesses the remarkable reciprocal property of representing in the time domain the Fourier transform of a rectangular spectrum in the frequency domain, and of representing in the frequency domain the transform of a rectangular pulse in the time domain. As may be seen from Fig.6 its value is unity at $(\omega t + \phi_n) = 0$ but becomes zero at all other points where $(\omega t + \phi_n)$ has a value equal to an integral multiple of π. By scaling the angular velocity ω so that ωt changes by π radians during each sampling interval t_s, and by adjusting A_n and ϕ_n so that the central peak coincides with a particular sample point, the function becomes

$$F_n(t) = A_n \frac{sin\left[\pi(t-t_n)/t_s\right]}{\pi(t-t_n)/t_s}$$

and $F_n(t)$ represents the time signal level at the sampling instant t_n, but makes no contribution at any other sampling instant.

The reconstruction consists, then, of a convolution technique.[2] This corresponds to passing the samples through an ideal low-pass filter of bandwidth equal to the reciprocal of twice the sampling interval. In this way each sample is replaced by a waveform $F_n(t)$ corresponding to the Fourier transform of an ideal filter characteristic. This is illustrated in Fig.4B but for clarity only two successive samples have been replaced by their corresponding functions of the form described. It will be noted that each waveform has zero value at all other sampling times so that the summation of all such waveforms for every sample taken

$$\sum_{n=1}^{n} F_n(t)$$

gives the reconstructed pulse passing through all the sample points as shown in Fig.4C.
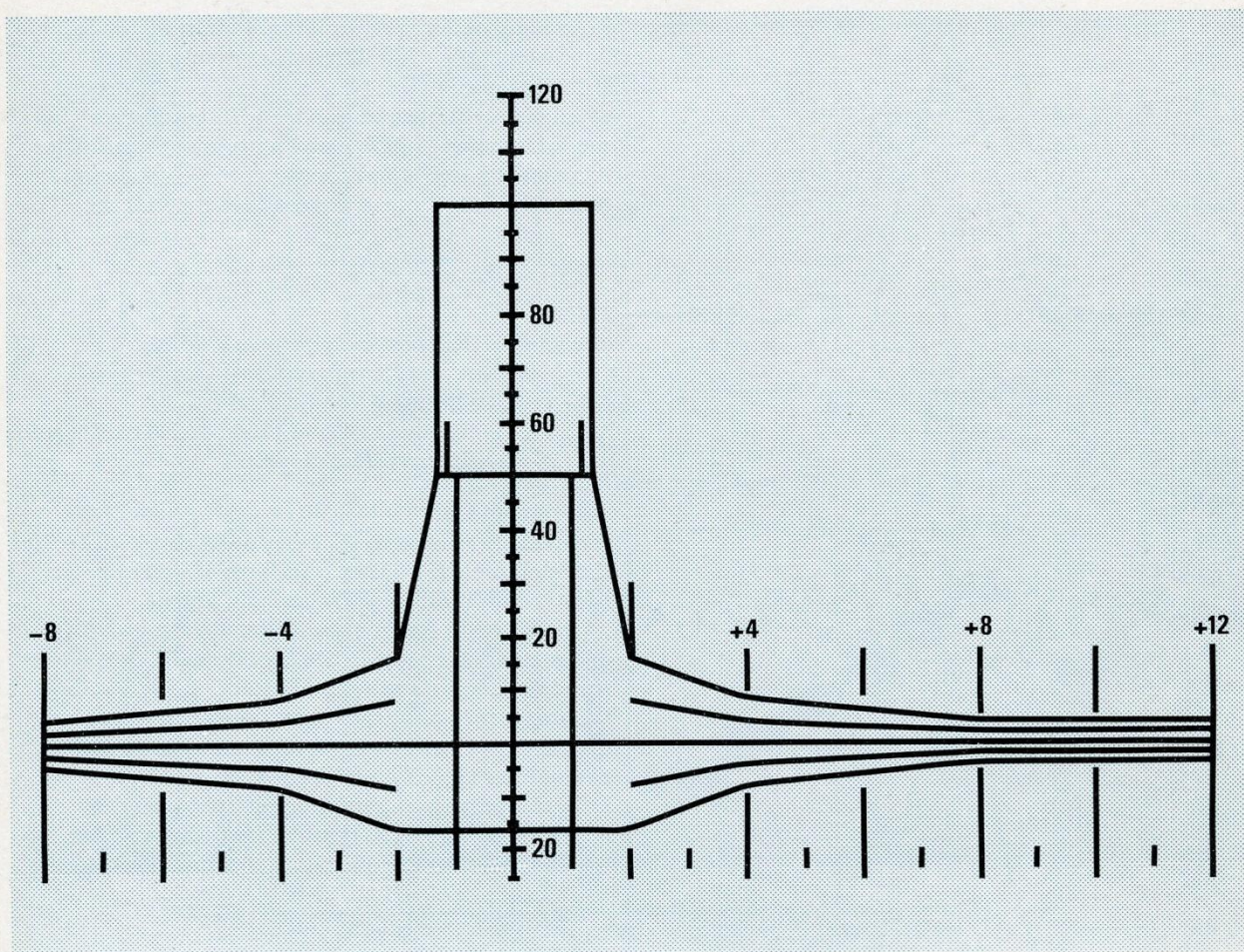
Fig.5. Measurement of the K-rating distortion factors is based, in both manual and automatic monitoring, upon comparing the received sine-squared pulse waveform with the graticule shown here. The limit lines shown are the 2% and 4% distortion limits which are used to assess the magnitude of the pulse waveform distortion.

The overall waveform error introduced by the digital filtering [8], [9] inherent on the process affects the K-rating by less than 0·3% for an ideal sine-squared pulse which, of course, contains small amounts of energy beyond 6·7 MHz. Such errors are generally smaller for practical pulses. Also, out-of-band frequency components cause the precise form of the reconstructed pulse to demonstrate a slight dependence on the sampling phase.

During interpolation, the program corrects for black level, tilt and amplitude, the latter quantity being also required for the derivation of the pulse-to-bar ratio K-rating. This is followed by a determination of the half amplitude width, which represents a further K-rating, and then by the establishment of the pulse centre. Finally, the waveform is stretched non-uniformly in the direction of the ordinate so as to translate the corresponding graticule into a series of equally spaced parallel lines. The maximum positive or negative excursion may then be identified as the K-rating for overshoots and echoes. Programs of this kind can be used to measure the K-ratings as well as many other waveform parameters such as those shown in Table 1.

Other measurements include the width, amplitude, rise and fall times of both the sync pulse and the colour burst, the blanking interval, low-frequency noise and flashing, high-frequency noise in the line-signals and sound-to-vision cross-talk.
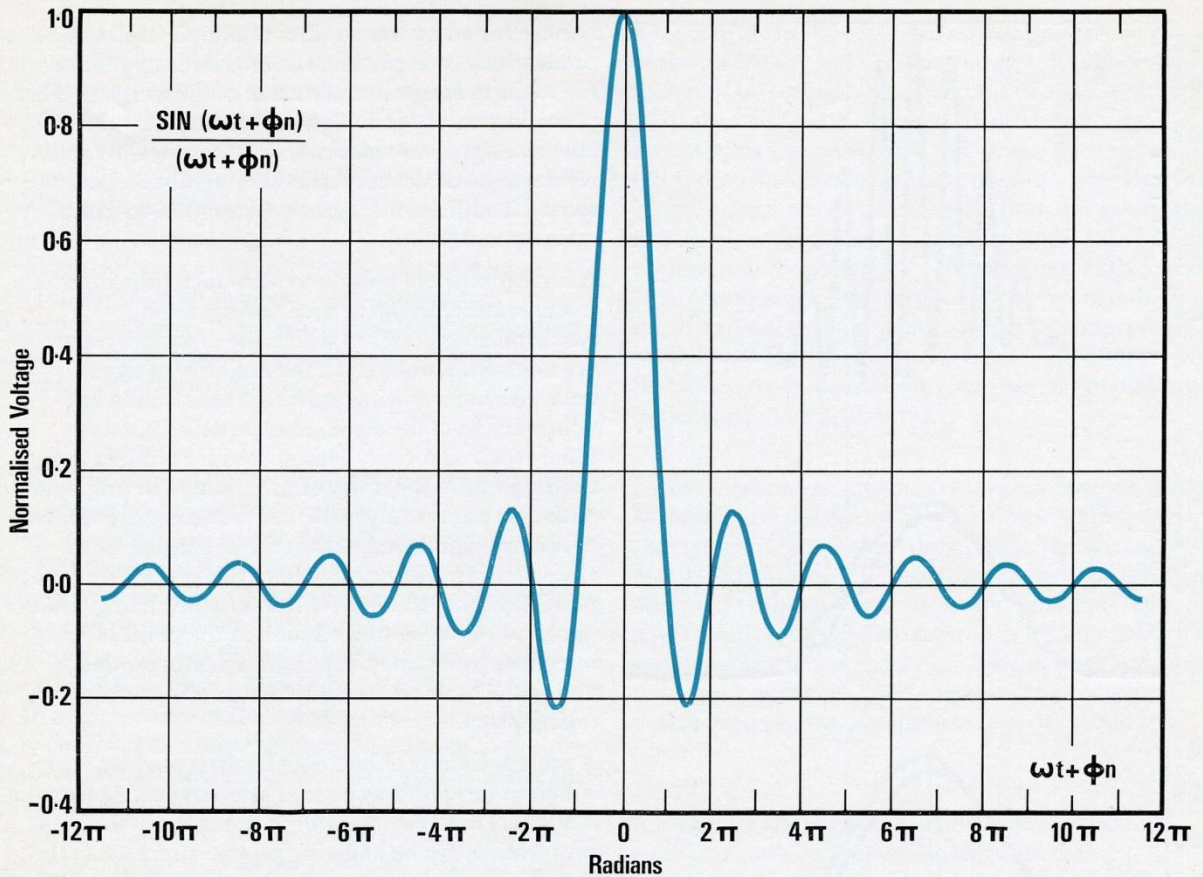
Fig.6. In order to interpolate between the sample points selected by the digitizing process, the sample values are operated upon by the function $\frac{\sin(\omega t + \phi n)}{(\omega t + \phi n)}$ illustrated here.

Table 1

Measurement	Relevance
Width of 2T pulse	Resolution
Tilt on 10 μs bar	Smear
Pulse/bar ratio	Amplitude/Frequency characteristic
2T echoes and rings	Phase response; echoes
10T pulse	Luminance/Chrominance gain and delay inequalities
Chrominance staircase	Differential gain and phase, also luminance linearity
Mini-bar, line 20	Luminance-chroma cross-talk.

Noise and the 2T pulse

Where the signal to be monitored is received off-air from a remote transmitter it is necessary to be able to analyse the waveform distortion inherent in the transmission despite the masking effects of any additional noise present on the signal at the monitoring point. In the case of the 2T pulse a method based on averaging is used. For a determination of the pulse height and shape corresponding sets of samples from successive alternate fields are summed together to form average values. One reason why samples are taken only on every other field is because of a recent proposal to replace the source originated ITS on each alternate field with a locally generated version at the appropriate IBA transmitter control centre. By adding and subtracting successive sets of samples the signal components are cancelled but the effective noise amplitude increases with the square root of the number of sets taken. When the peak value of this
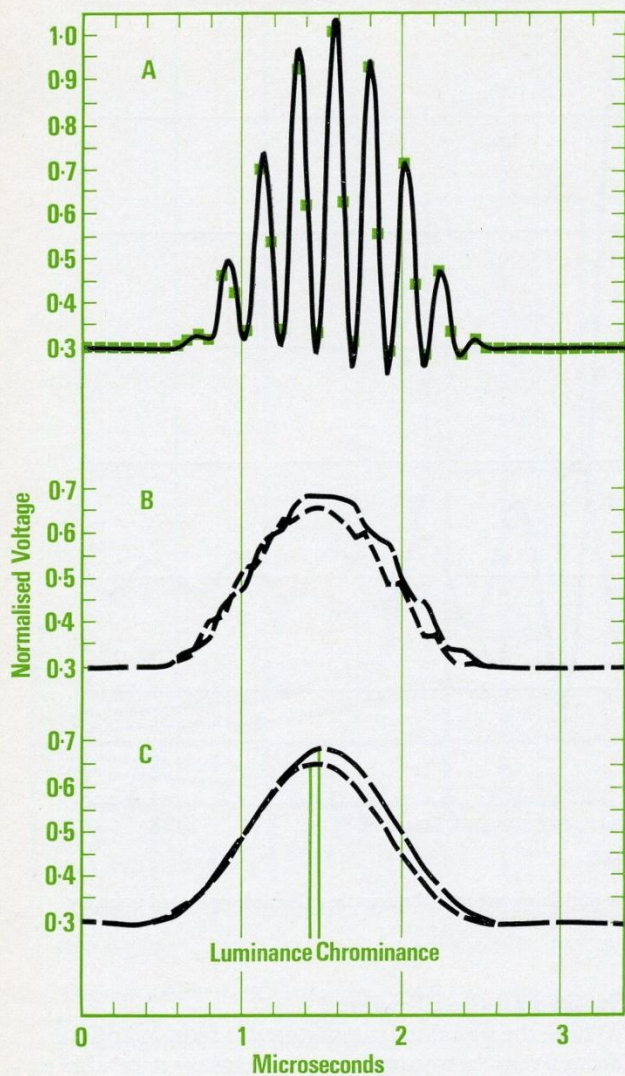
Fig.7. The 10T composite luminance and chrominance pulse shown at (A) is sampled at three times the subcarrier frequency, as indicated by the small squares. The computer then uses the geometry of three-phase ac power theory to pick out the mean level of the signal i.e. the luminance signal, and the peak value of the perturbation i.e. the chrominance signal. The derived curves are shown at (B). The irregularities are due to the relatively low sampling rate. The curves can be smoothed by removing the components above 1 MHz, as has been done in (C). Gain inequality is measured as the ratio between the peak amplitudes of these final curves and delay inequality as the interval between the pulse centres as defined by the half amplitude points. Accuracies of better than 1% in gain and 5 ns in delay are possible when dealing with line-fed signals.

noise, divided by the number of samples, falls below a predetermined limit then the required signals are fed to the computational section of the progam. This procedure results in a high probability that the effective signal-to-noise ratio is adequate for valid results to be achieved. An averaging time of one second is sufficient to improve the signal-to-noise ratio by 14 dB.

A further effect of noise is to introduce time jitter due to uncertainty in the precise timing of the synchronizing pulses to which the sampling pulses are referred. However, in the majority of cases delayed synchronizing pulses derived from a low-noise version of the signal may be substituted for those received off-air. This procedure reduces the timing jitter to the order of the changes in propagation path delay and study indicates that these are unlikely to become significant within the averaging times envisaged. In a few cases where this procedure is not possible highly stable fly-wheel synchronizing circuits may have to be employed both at the point of insertion, which may be geographically remote, and at the local centre where the monitoring is taking place.

A more serious problem may be presented by coherent forms of co-channel interference. At present it appears that the most effective measures for suppressing this lie in giving proper attention to the installation both of the receiver itself and of a suitably designed aerial although in the long term the use of precision-offset transmitter frequencies will assist. Apart from such effects, and neglecting errors which may originate in the conversion process, the averaging procedure permits K-ratings to be measured to an accuracy of 0.5% for signals with unweighted signal-to-noise ratios of 10 dB or less, provided sufficient sets of samples are available.

Extension to the chrominance parameters

The interpolation techniques described in relation to the 2T pulse have been extended to include the 10T composite pulse (2Tc pulse) and the chrominance staircase but programs utilizing these principles have proved unsatisfactory. For example, the technique may be used to reconstruct the lower envelope of the 10T pulse for subsequent analysis by an algorithm based on the well known oscilloscope method of assessment but misleading delay times are found to result from any appreciable luminance/chrominance gain inequality. Various alternative approaches have been tried and one such method, the most effective so far, employs principles

borrowed from three-phase ac power theory. A geometry adapted from this theory is used to relate sets of three samples taken at a rate equal to the third harmonic of the subcarrier frequency and permits a separate reconstruction of the luminance and chrominance components as in Fig.7. It has been shown, both theoretically and practically, that it is unnecessary in such cases for the sampling frequency to be accurately synchronized to the subcarrier as discrepancies of up to 0·05% can be tolerated. Appropriate corrections can be made in the program if, for example, a more accurate measurement of differential phase is required.

The application of this technique to the measurement of luminance/chrominance gain and delay inequalities is illustrated in Fig.7. Samples taken at the third harmonic of the subcarrier frequency, represented by the squares in Fig.7A, are processed in the computer and the separate chrominance and luminance pulses of Fig.7B calculated. These pulses are irregular in form but may be used directly to derive assessments of the gain and delay inequalities. The computation process takes the samples in groups of three and calculates the mean level of the luminance signal on the basis that the sum of the projections of the three sub-carrier phasors onto any axis through the phasor origin will be zero. Subtracting this from each of the three samples in turn gives three instantaneous values for the subcarrier. The peak subcarrier amplitude is therefore obtained by multiplying $\sqrt{(2/3)}$ by the square root of the sum of the squares of the three instantaneous values. The process is repeated using the last two of the three samples plus the next one, and so on.

By the process of digital filtering,[8] the 'derived pulses' of Fig.7B may be converted to those shown in Fig.7C where components of frequency greater than 1 MHz have been rejected. Each sample in a set of three is multiplied by a separate factor and the results summed to form a point on the filtered curve. This is equivalent to convoluting the train of samples with the function represented by the multiplying factors. Gain inequality is determined as the ratio of the peak amplitudes of these final curves and delay inequality as the interval between the pulse centres as defined by the half-amplitude points. When operating on a line-fed signal an accuracy better than 1% in gain and 5 ns in delay can be achieved.

Effect of noise on chrominance parameters
Noise effects are less predictable and the simple means of integration described for dealing with the 2T pulse need to be replaced by more complex methods for the composite 10T pulse. Alternatively, if it is not expedient to employ averaging techniques on the chrominance components then, for relatively low noise levels, some advantage may be taken of the approximately symmetrical distribution of the errors from individual computations by introducing a form of signal averaging at the stage corresponding to Fig.7B. The object is not so much to reconstruct the noise-free pulse envelope precisely as to deduce its centre and its peak height.

Differential phase and gain measurements are further hampered by the effects of quantization noise due to the reduced level of the subcarrier in the test signal compared with the 10T pulse and to the compromise accepted with regard to resolution in the present equipment. One possible approach is to increase receiver gain and insert a high-pass filter to remove the main luminance components of the test signal, both actions being accomplished under computer control.

A favoured alternative is to add to the incoming analogue signal a uniformly distributed and preferably random signal with a maximum value equal to one digit level. Figure 8 shows the reduction in the calculated mean error in measuring both differential phase and differential gain when uniform noise is added to the signal. The same diagram shows the effect of sampling frequency offset on the error.

It will be seen that for a signal without additional noise a frequency offset reduces the error in both measurements but particularly in the measurement of differential phase. A voltage ramp is also a uniformly distributed signal and in principle should give the same error-reduction as uniform random noise. The effects of other noise distributions have been investigated and Fig.8 also shows the error reduction due to adding noise with a distribution which is symmetrical and which follows the shape of the Gaussian, or normal distribution curve, having a variance equal to one digit level although it has since been shown that this value is not optimum. All the plots in Fig.8 were calculated for a mathematical model the amplitude of which was restricted to 20 quantization levels.
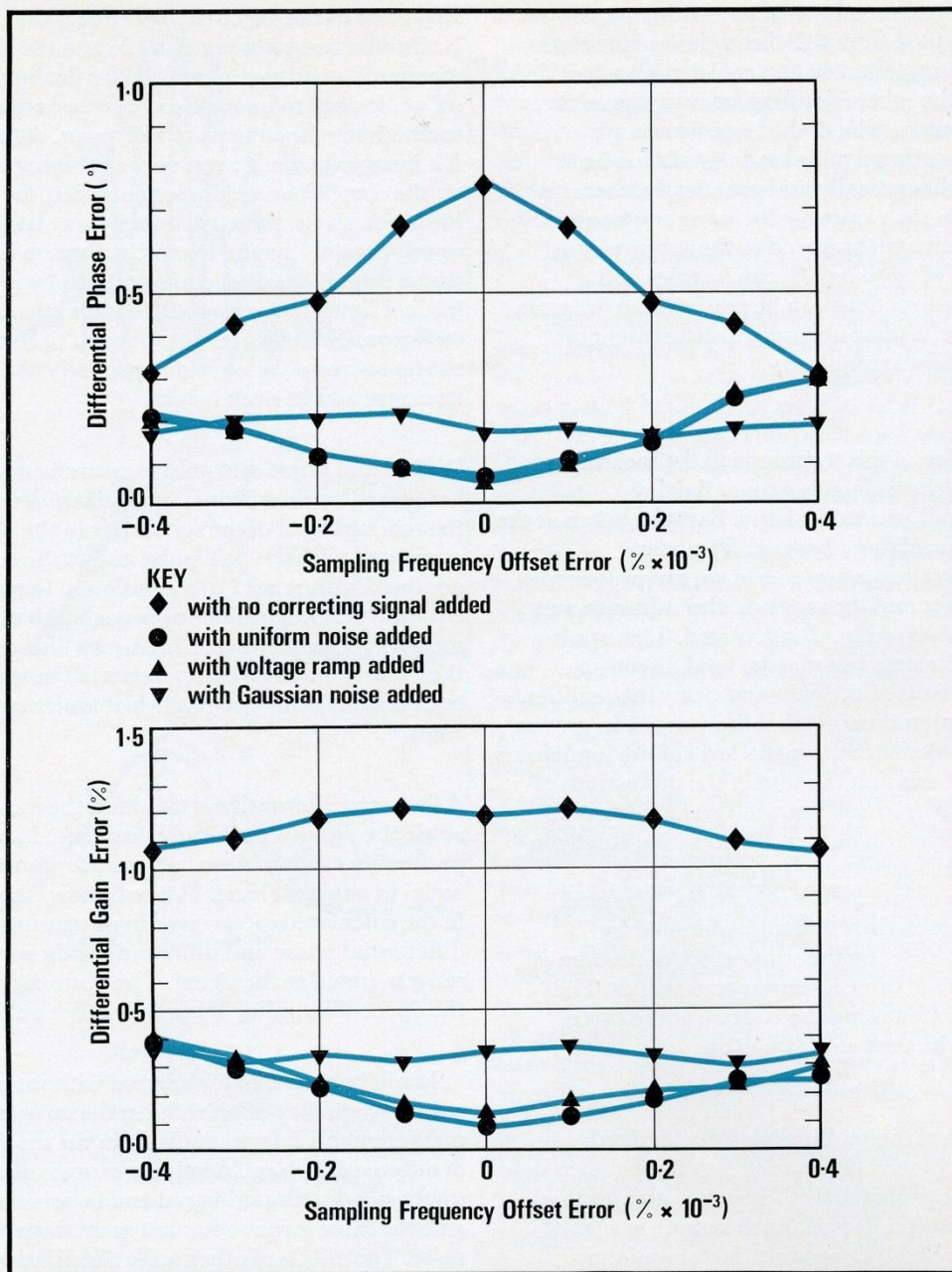
Fig.8. Various corrective processes can be undertaken to reduce the error in the measurement of differential phase and gain which arises from the finite number of quantization levels used. If the sampling frequency is off-set, then the computational error decreases. If noise is added to the signal before quantization, then the error is further reduced. Adding a voltage ramp waveform is identical, in principle, to adding uniform random noise to the analogue signal. Noise with a symmetrical but non-uniform distribution, such as a normal or Gaussian distribution, is also effective in reducing the error.

Conclusions

Investigations have shown that suitable methods are available for analysing insertion test signals by means of an on-line digital computer and of measuring the relevant transmission parameters with the required order of accuracy. The effects of relatively large amounts of extraneous noise present on signals being monitored off-air from a remote unattended transmitter appear to be most acute for the case of measuring differential phase. This is also a difficulty with the manual method. However, the autophase correction action of most PAL receivers makes differential phase a relatively unimportant parameter.

The philosophy behind the experimental system as described has been to provide a means of verifying that correct operation from test results could take place continuously. The results can be analysed to create statistical information about the operation which would then be available to management. In the longer term the continuous assessment of errors will allow immediate correction under computer control but only simple control actions, such as switching to stand-by equipment, would be initiated in the first system. More complex control, and all information concerned with subjective impressions of the picture quality, will be fed to the computer store from a keyboard at the manned control position.

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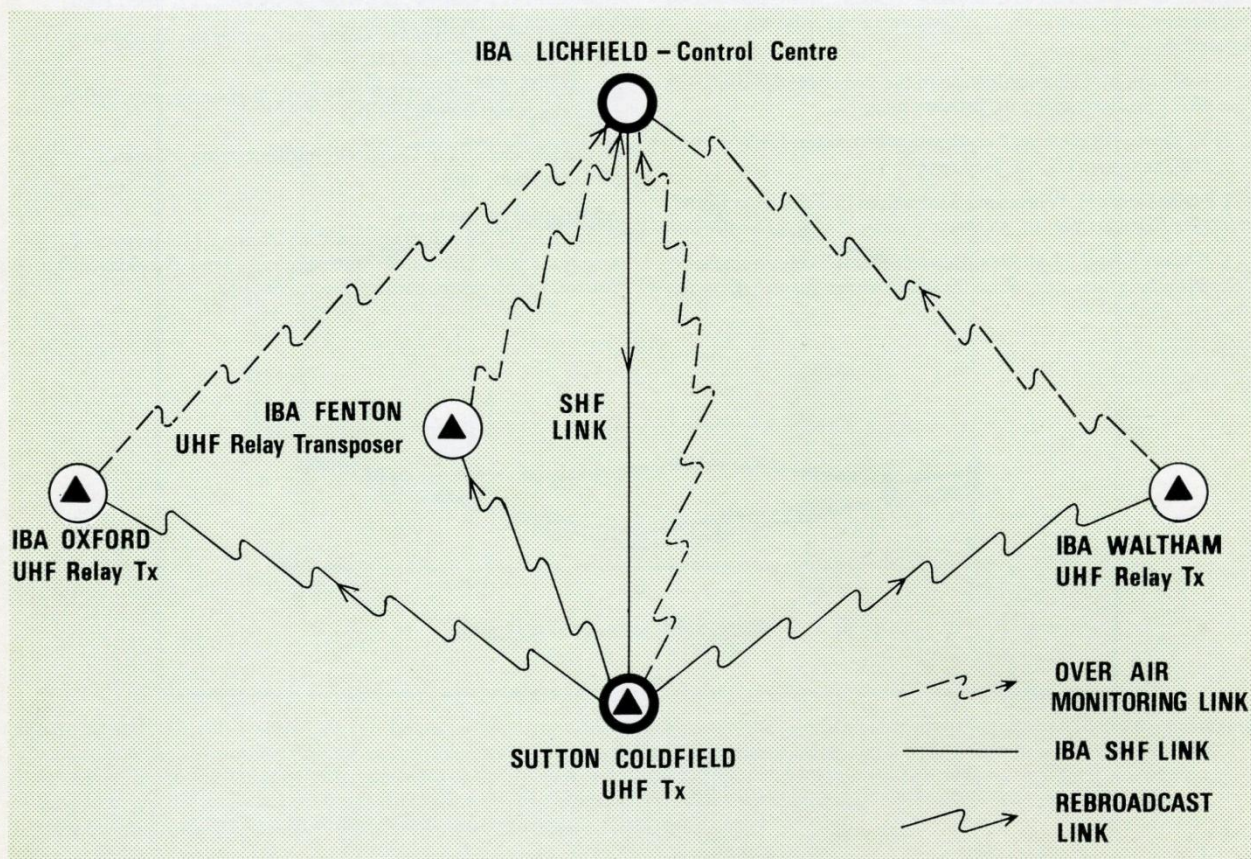
Fig.9. Programme distribution arrangements for part of the IBA's Midlands area. The UHF main station at Sutton Coldfield receives its 625-line programme feed from Lichfield via the shf link. The broadcast signals are then relayed on different channels at each of the other three stations shown and all four off-air signals are monitored automatically back at the Lichfield control centre.

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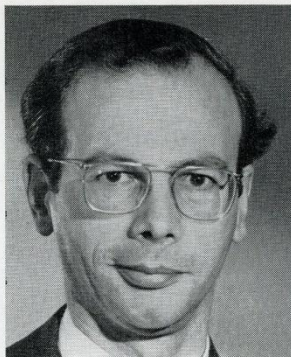
Experiments with a Computer in a Television Control and Monitoring Centre

by G A McKenzie

Synopsis

The proposals for the use of computers to monitor the performance of the IBA's unmanned UHF television transmitting stations have been described elsewhere in this volume together with some of the techniques which have been undergoing investigation by the Experimental and Development Department. Large scale field tests, known as the Lichfield experiments, have recently been conducted in support of this work and in particular to investigate the accuracy of measurements carried out on transmissions received from a distant station in the presence of noise and co-channel interference. The present article summarizes this work and gives the results obtained so far. The full programme of tests is not yet complete.

In recent years there has been an increasing interest among broadcasting engineers in methods of automation. It was the aim of early work in this field to mimic the actions of operations staff. At first, because of the large number of staff who were employed in monitoring the technical quality of programmes, work was concentrated on methods of automatic monitoring. Early work was concerned with automatic monitoring of the sound signal[10] but in more recent years, and following Lewis's work on television test signals,[11] automatic television monitors using such signals have been widely reported. [12, 13, 14] These systems make use of test signals inserted into the field blanking time of the television signal and are consequently known as 'insertion test signals'.

However, automation of engineering operations is not to be confined merely to automatic monitoring, or even to automatic monitoring followed by simple automatic control actions. In earlier papers [15, 16, 17] the author and his colleagues have drawn attention to wider implications. These include such matters as the generation and the use of statistics for both short and long term management of the operation. The essential element of true automation is that it involves management, and this in turn demands study of the basic structure and aims of the organisation.

The proposals rely on the use of small computers at each of several regional control centres with communication links to headquarters. That most aspects of the proposals were fully feasible seemed adequately supported elsewhere, for example in articles such as references 18 to 20. However, to support some more controversial aspects of the proposals it was necessary to mount a large-scale field experiment to investigate in particular the off-air waveform monitoring of distant UHF television relay stations together with their aerial and feeder systems – particularly when noise and co-channel interference were present. Such monitoring was certainly not possible by conventional methods depending upon a measuring oscilloscope. Some of the results given in this paper relate to the use of a computer for this particular task at the IBA's control station at Lichfield. At the time of writing some of the work is still in progress.

By way of further introduction, the programme distribution arrangements for the IBA's Midlands area are shown in the diagram of Fig.9.
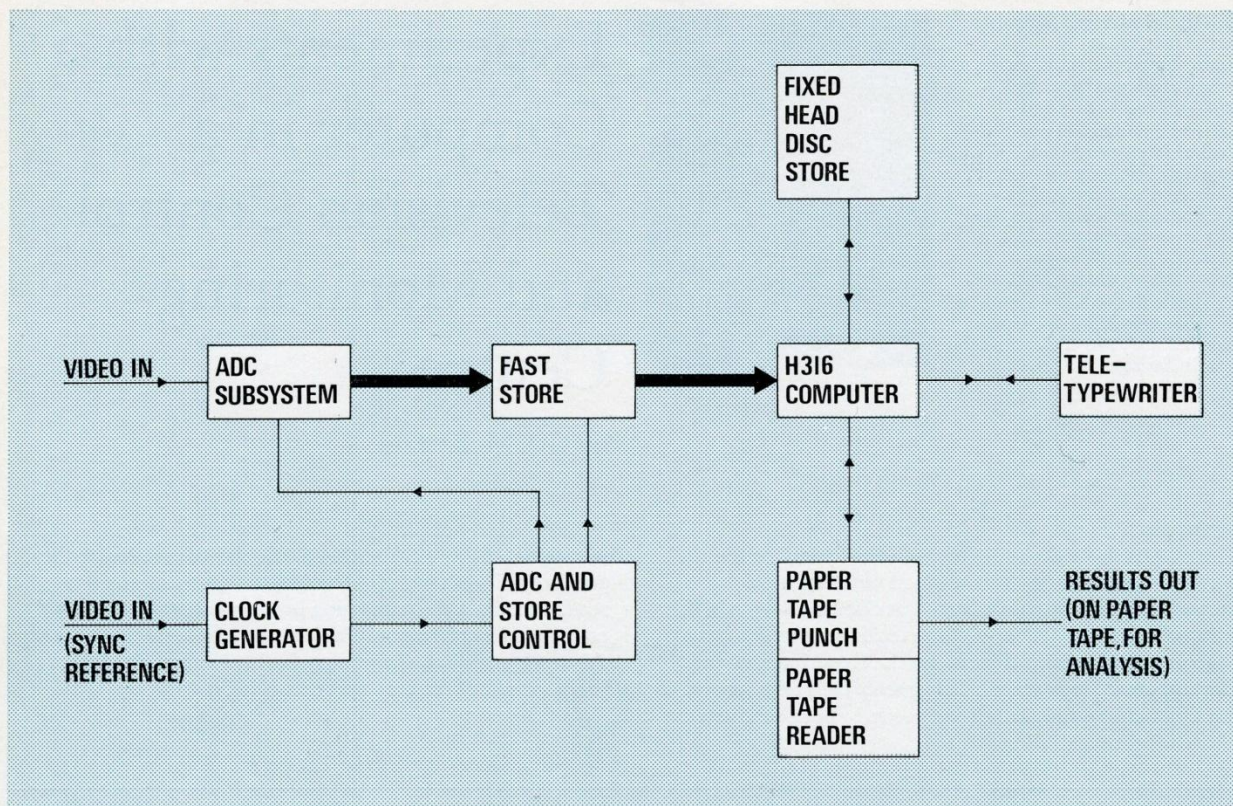
Fig.10. Block schematic of the first phase experimental television waveform measuring equipment assembled at Lichfield. Video signals containing the insertion test signals (ITS) which are to be measured are fed into the computer via the high speed analogue-to-digital converter (ADC). 'Clean' syncs, suitably delayed, can be fed into a separate input. Operational programs are contained in the disc store and the system is controlled from the teletypewriter. The computed results are punched onto paper tape from whence they are available for analysis.

The experimental system

The system which has been assembled at Lichfield is represented by the block diagram of Fig.10. A photograph of the equipment is given in Fig.11.

The input video signals containing the insertion test signals which are to be measured are fed through the computer-controlled switch to the high-speed analogue-to-digital converter. Successive samples of the signal are converted to a parallel eight-bit stream, samples being taken at approximately 13 million times per second. A group of successive sample values occurring during the test line is stored in a high speed semi-conductor store and then subsequently fed to the computer. In the computer, calculations are made and the results of the calculations are punched onto paper tape. The disc store contains some operational programs and the

teletypewriter is used for control of the system and also occasionally for output information.

A full description of the software is beyond the scope of this article. Briefly, the approach has been based on the use of the manufacturer's 'Real Time Executive' software. Programming has been by a combined team of programmers and engineers. The programmers have concentrated on the system aspects and modifications to the executive software, while the engineers have produced the waveform analysis program 'modules'. Programming has been done in an 'assembly' language.[23] The structure of the software is generally indicated by the schematic diagram of Fig.12. One example of a typical waveform parameter calculation program may be found in reference,[21] though that example is written in the 'Fortran' programming language.

Table 2. Means and standard deviations of measurements

No. of measurements		Local Signal (164) Mean	Dev	Sutton C'field (186) Mean	Dev	Waltham (163) Mean	Dev	Fenton (77) Mean	Dev
K pulse width	(%)	−0·3	0·0	−3·9	0·1	−4·0	0·1	−3·3	0·2
K pulse echoes	(%)	1·8	0·1	4·3	0·2	4·8	0·3	5·2	0·5
K bar	(%)	0·5	0·0	1·6	0·2	3·2	0·2	2·0	0·5
K pulse/bar	(%)	0·1	0·1	2·5	0·1	1·6	0·2	2·9	0·4
Chrominance/luminance delay	(ns)	−8·0	0·7	0·4	0·4	−20·1	3·3	−59·0	7·0
Chrominance/luminance gain	(%)	3·8	0·4	3·6	1·1	3·1	1·2	19·6	2·8

The experiments may be described in five main groupings as follows:

1. *Experiments to investigate the statistical properties of measurements on sources having high signal-to-noise ratios.* Some typical results for signals from the IBA network are given in Fig.13 in the form of graphs showing the cumulative distributions of 164 measurements of each insertion test signal parameter. Each set of six measurements took approximately three seconds to make. After one set of measurements the parameters were known to an accuracy indicated by the mean and standard deviations given in Table 2. It is important to note for example that after 30 seconds the mean of ten measurements would be available. The standard deviation of a set of ten such means would be approximately one third of that shown in Table 2.

Fig.11. General view of the experimental system for the first phase experiments. The Honeywell H316 computer may be seen near the top of the left-hand rack. The disc store and its power supply are below it and the computer interface units developed by the IBA are in the right hand rack.
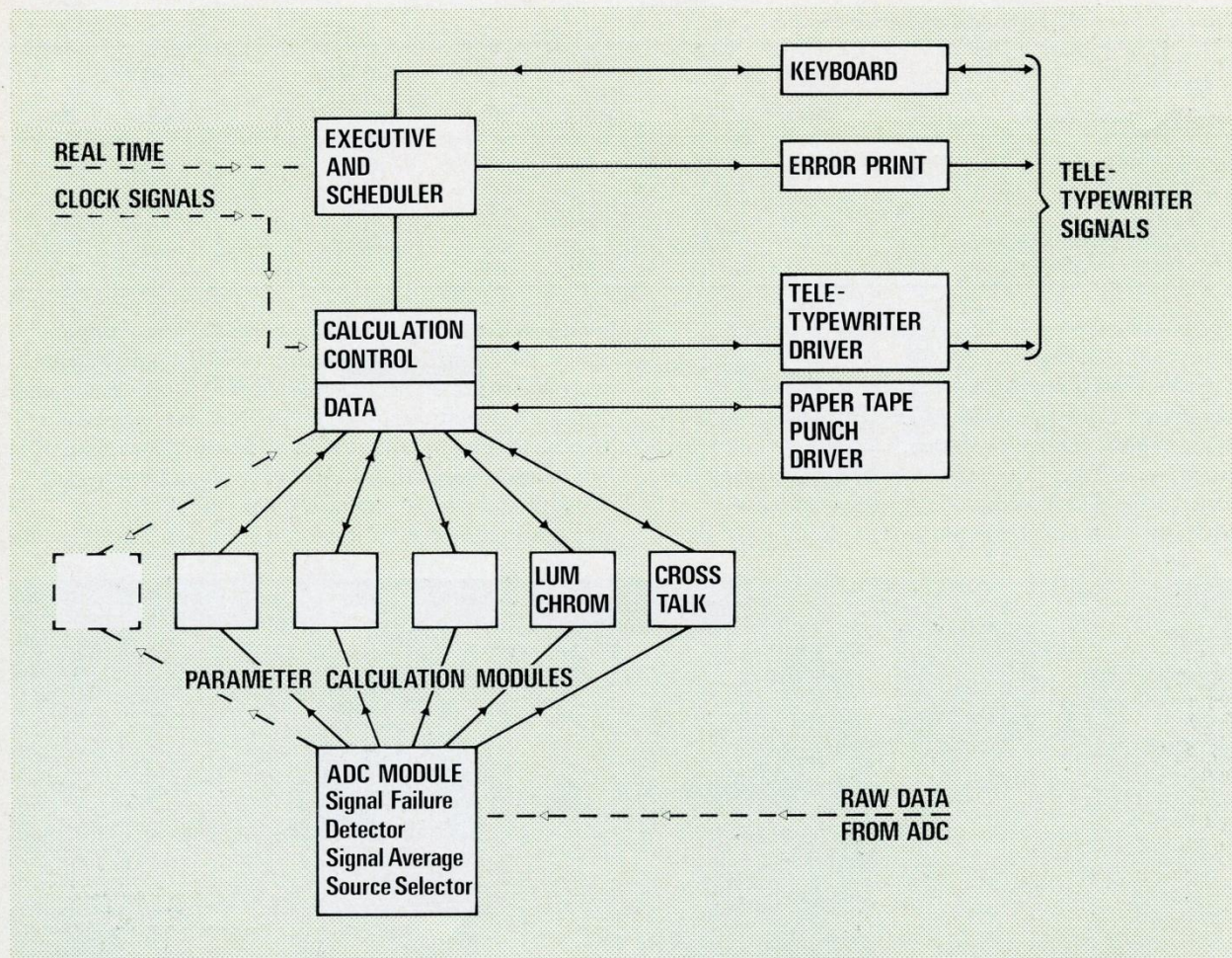
Fig.12. The Software. The diagram shows the modular structure of the programs used for the first (experimental) phase.

Fig.13. Relative cumulative distributions of 2T pulse-and-bar K-factors and chrominance to luminance ratios measured on signals taken from the IBA network and therefore having a high signal/noise ratio. The number of measurements made of each parameter was 164. The ordinate shows the percentage of all measurements taken which lay below the abscissa value.
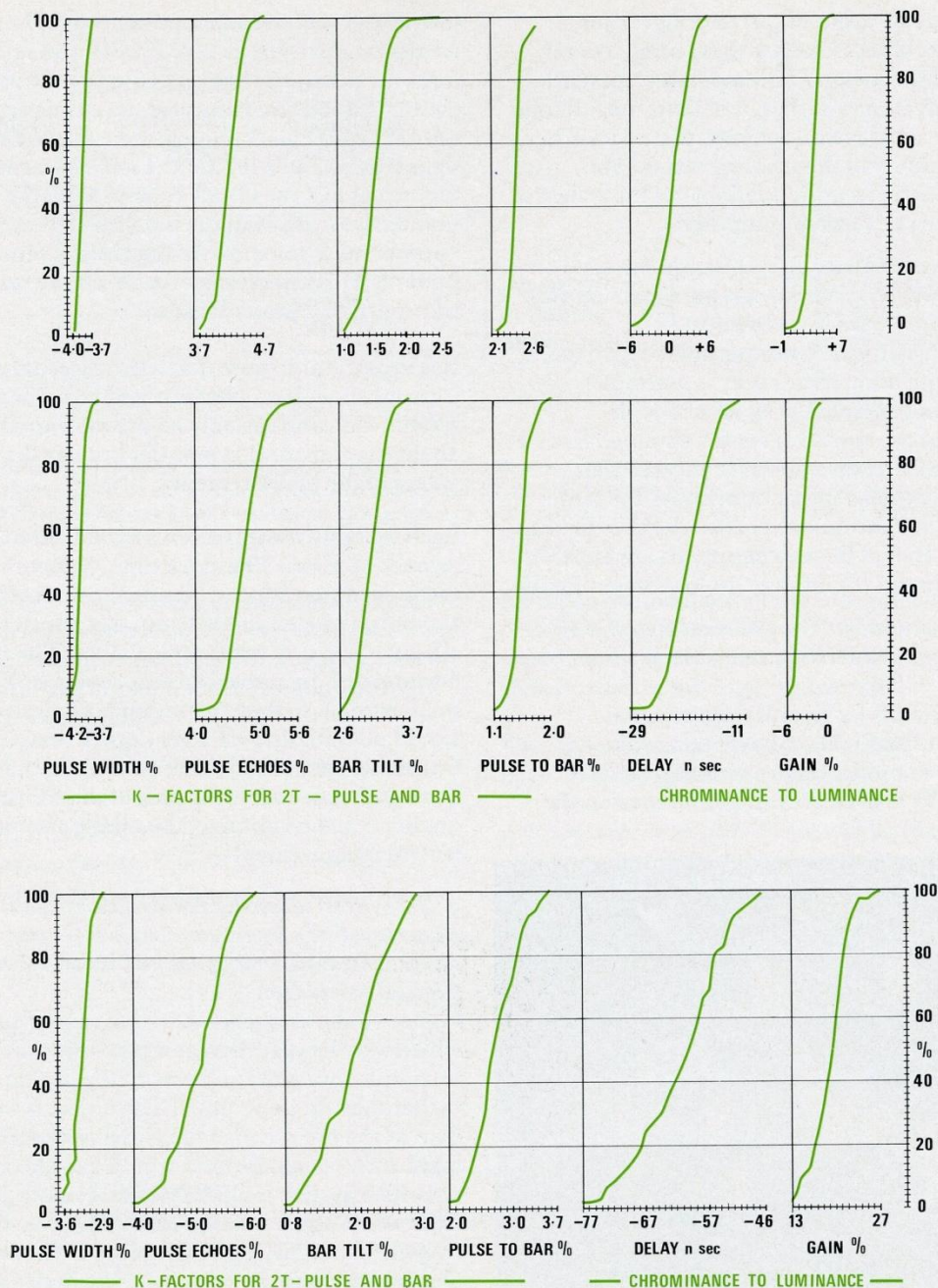
Fig.14. Results taken off-air in respect of the main station Sutton Coldfield (upper set of curves) and two of its relays Waltham† (middle set of curves) and Fenton (lower set of curves). The number of measurements for each parameter in the three cases were respectively 186, 163, 77. The results for the comparatively weak and noisy signals from the IBA transposer at Fenton show a much greater spread than those for the strong signals from Sutton Coldfield.

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†Because it receives its programme feed from an off-air RBR link from Sutton Coldfield, for the purposes of this article Waltham is referred to as a relay station. But in consideration of its size (erp of 10 kW or greater) it is at other times classified as a main station and is referred to as such in all other literature published by the IBA.

Advantage may be taken of the very short time needed for a set of measurements, by using several results to form the mean. (This indicates a potential operational advantage in that, if desired the full time available for a set of measurements may be used to improve the quality of the measurements. The flexibility implied is readily available as the system is based on a general purpose computer.)

2. *Experiments to investigate the relationship between computer measurements of the insertion test signals and those made by conventional manual methods.*

At the time of writing, it is not possible to give more than a brief indication of this very important relationship. In general, it may be said with confidence that the spread of results obtained from a series of manual measurements far exceeds that obtained by computer measurements on the same signal, even when the amount of interference present is quite small. In fact these experiments are expected to yield meaningful results only for low-noise signals.

3. *Experiments to investigate the statistical properties of measurements of distant UHF transmissions by off-air reception.*

Some typical results for signals from one main station, Sutton Coldfield, and two relay stations, Waltham and Fenton, are given in the graphs of Fig.14. The effects of electrical interference on the
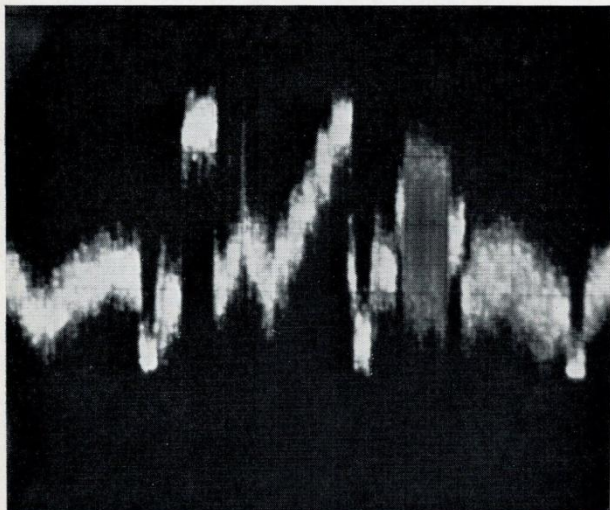
Fig.15. Photograph of a typical insertion test signal waveform at the input to the Lichfield computer system, received off-air from Fenton. In addition to noise some co-channel interference (from Sandy Heath) was also present as can be seen from the undulations visible in the baseline.

distributions of the measurements may be seen. The results for the comparatively weak and noisy signals from the IBA transposer at Fenton show a much greater spread than those for the strong signals from Sutton Coldfield. A photograph of insertion test signals as received off-air at Lichfield from Fenton is given in Fig.15. It may be seen from the undulations visible in the baseline that as well as receiver noise some co-channel interference was present. This interference was from the IBA transmitter at Sandy Heath.

It is important to note that these measurements were taken with an uncalibrated receiver and aerial system. Conclusions may be drawn from the graphs about the statistical properties but not the absolute values of the measurements.

Each set of six measurements from Fenton took ten seconds to make. The extra time, compared with that mentioned in section 1, was due to an adaptive signal averaging process in the computer which reduced the effects of noise on the sample values. The standard deviation of the measurements shown in Table 2 was small enough so that any individual measurement would potentially give a very quick reassurance that transmissions were to the required standard of quality. A more accurate idea of the transmission quality could be obtained by taking the mean of several measurements.

4. *Experiments to investigate the relationship between measurements of a transmission made at the transmitting station, with those made off-air both inside and outside the principal service area.*

Figure 16 shows a schematic diagram of equipment which may be placed at a remote transmitting station to sample the signal and record the digital values of the samples on paper tape. The object is to collect data at the remote point as closely as possible to the manner in which the data would be collected by the computer system if placed at that remote point. The equipment uses a slow speed analogue-to-digital converter and instead of sampling within one line of one field spreads the samples of the insertion test signal over several fields broadly in the manner reported by Wise.[22]

The block diagram of Fig.16 shows that the input signal is obtained from a demodulator. This latter has been carefully aligned to have the same response characteristics as the receiver in use at the remote receiving site.
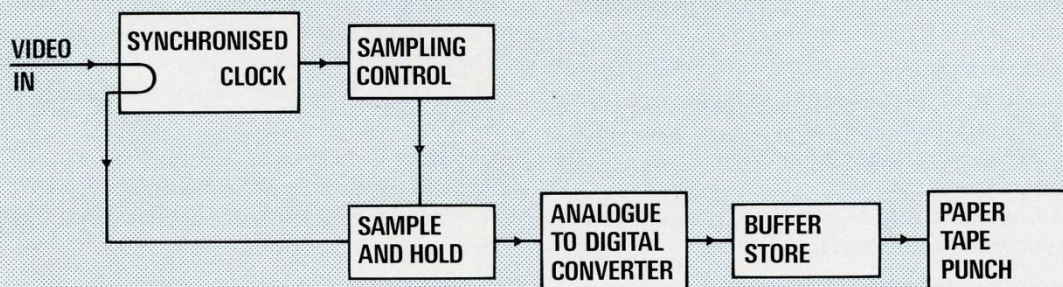
Fig.16. Block diagram of equipment which may be used at a remote transmitting station, or elsewhere, for taking samples of ITS and recording the digital values on paper tape. It enables a comparison to be made between results taken actually at the transmitter and those obtained off-air at the computer installation. The equipment uses a slow analogue-to-digital converter and spreads the sampling process over several fields.

It is also our intention to make measurements in a vehicle at various points within the service area of the transmitting station, so that any distortions produced by the transmitting aerials and feeders may be more readily taken into account.

Work on this section of the experiment is still at an early stage.

5. *Experiments to investigate the performance of an experimental monitoring system in operational conditions.* At the time of writing preparations are being made

for an operational test of the computer as a means of monitoring transmissions. This experiment will be based on the system illustrated in Fig.17. The structure of the software is illustrated in Fig.18.

The operational facilities provided by this experimental system are as follows:

a Signals to be monitored. These will be the signals transmitted from IBA transmitters at Sutton Coldfield, Waltham, Oxford, and Sandy Heath.
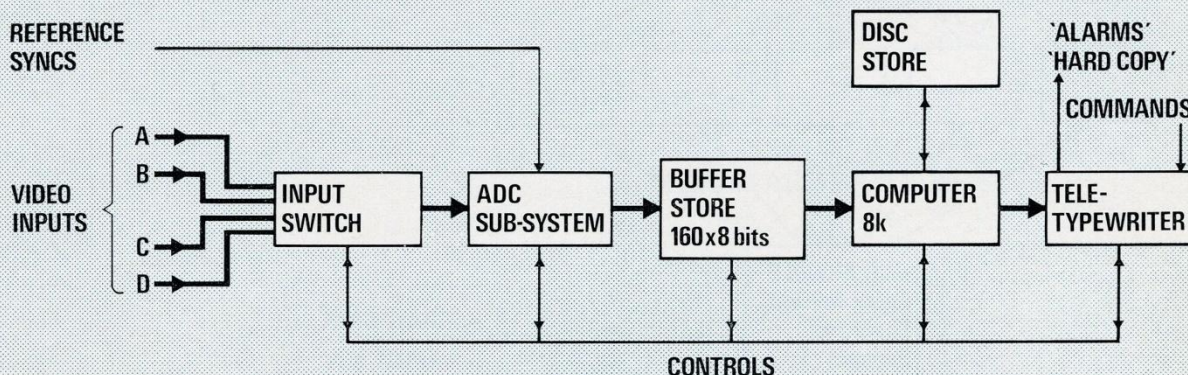
Fig.17. Block schematic of the computer system now being prepared for a series of tests under operational conditions. This work is known as the 'operational phase'.

(Sandy Heath is a transmitter in a different IBA Region).

b Parameters to be monitored. These will be restricted to include:

Five luminance parameters:
K factors for 2T pulse width and lobes, for the bar and for the 2T pulse/bar ratio.
Also, luminance (staircase) non-linearity.

Five sync parameters:
Colour burst amplitude, duration, position and line sync pulse width and amplitude.

Five chrominance parameters:
Differential phase, differential gain, chrominance-to-luminance gain and delay ratios, and chrominance/luminance crosstalk.

c Alarms. If any parameter is found to be out of limit an alarm will occur and a set of results for the offending station will be typed on the teletypewriter against clock time. (If errors detected at Waltham and Oxford occur simultaneously at Sutton Coldfield, then Sutton Coldfield will show the alarm condition first.)

d Print-out of measurements. A complete set of measurements may be obtained on the teletypewriter at any time in response to a typed two letter code.

Conclusions
Though the experiments described are not yet complete it is already possible to draw some conclusions:
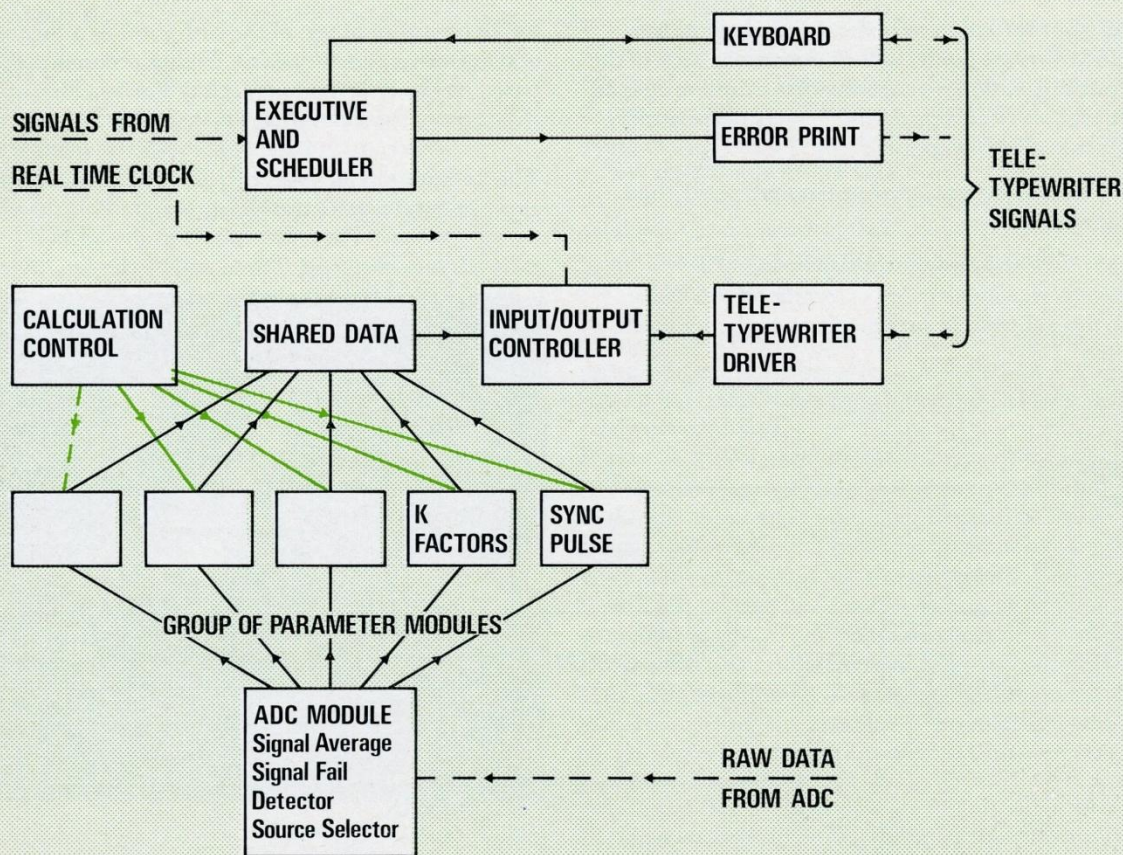

Fig. 18. The software for the operational phase. The diagram shows the modular structure of the programs for these experiments.

1. Measurements of video waveforms, including some which were perturbed by strong noise and periodic interferences, have been made using a fast analogue-to-digital converter and a general purpose digital computer.

2. The statistical distributions of such measurements appear to be normal (Gaussian).

3. The standard deviations of sets of measurements so obtained appear consistent with the quality of the signals.

4. The fact that the system has been based on a general-purpose computer has made it easy to vary the mode of operation of the system as demanded by the different experiments. This also has significance for possible future operational use of such a system.

5. The same fact has made it easy to obtain records in written and in computer-compatible form for further statistical analysis and archival purposes. This again has great significance for operational applications.

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Fig.19. The mast is raised by means of a petrol driven compressor fitted to the trailer. Before raising, the aerial is first attached to the uppermost section and the feeder cable fed through eyelets located on collars at the top of the eight lower sections.

Fig.20. When all nine sections have been fully extended a height of almost 100 ft is attained. See also Figs. 23 and 24.

ROGER BYRNE, CEng, MIERE, joined the IBA in 1962 from The Marconi Company where he had been engaged on a number of projects, amongst them colour television research. His early work with the IBA was in links planning and in 1968 he became Head of the Authority's new Service Area Planning Section. He has since served on a number of international Working Parties and Study Groups. A Londoner by birth, he lives with his wife and two children in Essex.
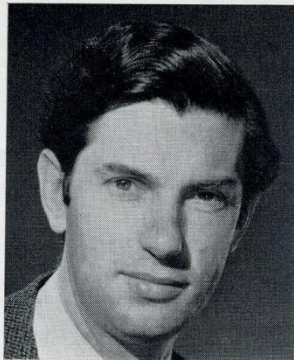
Off-Air Reception Measurement at Proposed Sites for UHF Television Relay Stations

by R J Byrne

Synopsis

The plan for establishing a national broadcasting service using the 625-line colour system (System I) in UHF bands IV and V involves putting into operation some 55 main transmitting stations and something over 400 lower power relay stations. It was agreed in the early planning stages that all UHF transmitters serving a given area would be co-sited and that roughly half the total number of sites should be owned by the IBA. In considering suitable sites for the relay stations consideration has to be given to the reception conditions from the appropriate main station from which the signals for re-broadcasting are taken off-air. In certain cases it is not possible to obtain the signal direct from a main station and it may be then necessary to consider feeding two relays in series.

It is therefore necessary to be able to measure the received signal parameters accurately at precise locations as a preliminary to site selection. A special mobile unit was constructed containing all the required test equipment and featuring a telescopic mast of nine sections enabling the receiver aerials to be raised to heights of up to 30 metres above ground level. Methods of signal measurement and the specification of performance required are discussed in detail.

Subsequent to the 1961 EBU Stockholm Conference[24] at which were formulated the basic overall plans for main transmitting stations, together with frequencies and other basic transmission characteristics that would be required throughout Europe for eventual operation in Bands IV and V, the UK broadcasting authorities commenced planning for the (eventually) four-channel operations using, as far as possible, existing BBC or IBA sites. It had already been agreed that all UHF transmitting stations for any one area would be co-sited and also that ultimately there should be an approximately equal division of ownership of sites between the BBC and IBA, this apportionment to be inclusive of all existing sites that would be utilized.

It has transpired that about 55 main stations with an erp greater than 10 kW are required together with between 400 and 500 relay stations with erp's equal to or less than 10 kW to supplement the service both within and between main station coverages.

Ideally, all relay stations should be able to receive programme feeds by direct reception from the associated main transmitting station. In practice some will be second generation relay stations which receive signals from nearby major relay stations.

Direct feed of relay stations may not be practicable in all cases by reason of unacceptable quality of received signal level due to path attenuation, signal distortion or interference from either co-channel or adjacent channel stations. In such cases it is necessary to consider the use of SHF links either for direct transmission of the signal from the main station or via intermediate off-air pick-up points.

Although a prospective relay site may be considered satisfactory with regard to coverage if that relay station, as will most often be the case, is to be dependent on direct reception of another station for programme feed, it is important to verify that an adequate signal can be received free from distortion or interference that woud degrade the subsequent re-transmission to an unacceptable degree.

The signal levels can usually be readily estimated by the use of various radio wave propagation prediction techniques on which subject a substantial number of authoritative documents and technical papers have been produced over the years.

With the requirement of being able to receive at each UHF relay site for re-transmission of up to four signals within an overall band of not less than 88 MHz, each having a bandwidth of eight MHz and containing sound, luminance and chrominance information, the quality of the received signal at the aerial terminals is of considerable importance.

There are four aspects of signal distortion which are attributable to radio wave propagation and are, therefore, influenced by the site:

a received field strength which controls the signal/ noise ratio of the transmitted signal

b variations in the received signal level across the channel

c presence of delayed images due to multipath reception

d presence of interfering signals

In the case of a typical relay station, the receiving aerial is likely to be mounted at between 15 and 30 metres agl. Measurements of the above parameters will determine the optimum height and also show whether the signal quality is adequate for re-broadcasting.

Field strength

The minimum field strength required for satisfactory reception in terms of signal/noise ratio, can readily be determined for a receiving installation of known parameters from basically knowing how much a 625-line picture is degraded by a given ratio of peak-to-peak picture signal and rms noise.

To the calculated figure it is then necessary to add allowances in respect of such factors as anticipated signal fading over the transmission path, deterioration in equipment performance and probable minimum signal/noise ratio expected on the received signal due to the performance of the programme link from the main station and of the transmitter itself. A further allowance in this respect should be made where the signal source is in fact receiving its own signal by direct reception as is the case for a few main stations and will certainly apply in the future where it becomes necessary to operate two or more relays in tandem.

A minimum required field strength of 80 dB/μV/m was proposed after making due allowances for the factors referred to above. However, for very short paths subject to negligible signal fading and very low power relays with a maximum erp of about 100 watts and serving only a small population, this criteria could reasonably be relaxed to 76 dB/μV/m.

The above figures are in respect of an operating frequency of approximately 850 MHz, i.e. in the upper part of Band V. If the same standards are to be applied throughout the UHF band, then for a frequency of 470 MHz in lower Band IV there is a 5 dB improvement in the relationship between incident field strength for the half-wave dipole and the terminal emf. With this reduction in frequency, there would be an approximate reduction in receiving aerial system gain of about 1 dB, thus, in the absence of other determinant factors, a Band IV receiving site that does not fulfil the basic field strength requirement of 80 dB/μV/m may still be considered satisfactory for field strength levels down to 76 dB/μV/m.

There is, however, one important feature to be taken into account, particularly before considering a field strength of less than 80 dB/μV/m as acceptable, and that is the field strength required to ensure adequate protection against co-channel interference. This is dealt with in a subsequent section.

Since it is proposed that at most relay stations a common receiving aerial will be used for the eventual reception of four channels, it is important that field strength measurements, and indeed all other measurements, should be taken over a substantial height range up to the maximum height at which the receiving aerial system can conveniently be mounted. Detailed height/gain measurements should then give an indication of any standing wave pattern resulting in variations in signal level. It is likely that similar, but not necessarily coincident, variations would occur on all four channels.

When possible, the measurements should be repeated on a number of occasions and, in the case of substantial variations occurring, at alternative locations on the same general site area since a lateral displacement of a few metres can have considerable effect on field strength (location) distributions in Bands IV and V. Field strength recordings should, if possible, be made at prospective receiving sites over a minimum period of about two days where it is

thought that there is a necessity to verify the short term stability of the received signal.

Channel variations

In addition to the field strength variations at the vision carrier frequency, there is also to be considered the variations that occur over an 8 MHz channel spectrum.

Analysis of the extensive UHF field trials carried out by the BBC/IBA/GPO in 1962–3 showed that for 80% of locations the chrominance/luminance ratios were up to ± 3 dB relative to the transmitted value; the corresponding range for sound/vision ratio was ± 5 dB on the nominal value. Subsequent measurements of the current UHF services have tended to support these earlier assessments.

A difference of ± 2 dB between the mean value taken over a range of aerial heights and the nominal value for sound/vision or chrominance/luminance is not expected to be troublesome. In fact, satisfactory reception has been reported during tests carried out by the IBA in which the sound/vision ratio was increased to 10 dB, i.e. 3 dB greater than the nominal ratio.

It is usual for the site measurements to be first assessed so as to ensure that this mean/nominal ratio is complied with and then that the sound/vision and chrominance/luminance ratio for each measurement does not differ by more than 2 dB from this derived mean value when the height of the receiving aerial is varied over a range of at least ± 3 metres about the optimum height.

Delayed images

Delayed images due to multipath propagation may well result when the relay station is sited in the midst of, or close to, mountains or irregular terrain and also when sited in the proximity of multi-storey or industrial development, an inherent hazard with regard to town 'fill-in' relays.

Subjective impairment due to delayed images may be assessed on the basis of measurements of the amplitude and delay relative to the primary signal or the distortion may be expressed in terms of the K rating factor.[25]

Previously published work[26] indicates that for a delay greater than $0.6\mu s$, a just perceptible impairment is caused by a delayed image 34 dB below the wanted signal. For delays of less than $0.6\mu s$ the delayed image amplitude should not be greater than -29 dB relative to the wanted signal. A delayed image 34 dB

below the signal level represents an amplitude of 2% and -29 dB an amplitude of about 3.5%.

For the 625-line system, if a 2T pulse is accompanied by an echo with a delay of 0.8 μs or greater, the equivalent K rating is numerically equal to the percentage amplitude of the echo, i.e. if the amplitude of a delayed image is 2%, this represents a K rating of 2%. For shorter delay times, the same K rating applies to greater amplitudes on a progressive scale and this forms the basis of the familiar K rating graticule used on an oscilloscope to facilitate the measurement of performance of television circuits and rapidly expressing the overall distortion in terms of maximum K rating. An example of the K rating graticule is shown in Fig.21 with the addition of amplitude levels of 3.5% from 0 to 6T and 2% above 6T. For the 625-line system I as used in the United Kingdom 0.1 $\mu s = 1$T.

From Fig.21 it can be seen that for a ghost image, delayed by 4T or more, a K rating of 2% corresponds very closely to the limits suggested above. For shorter delays, however, the limit of 29 dB becomes progressively more stringent than a K rating of 2%. In this range, and particularly for delays of less than 2T, the effect is more visible as a blurring and increase or decrease in saturation of the main image. This may be more readily taken into account if the assessment of the chrominance/luminance inequality is carried out by a waveform method using a 2Tc pulse. It may in that case be sufficient to adopt a K rating limit of 2% for all delayed images.

Since site testing measurements are not always performed under ideal conditions as in a laboratory, studio, transmitter or switching centre it may sometimes be convenient or advisable to make a supporting visual assessment on a picture monitor of the distortion due to delayed images.

Interfering signals

Subjective tests on both sound and vision should be made in order to detect the presence of various forms of man-made interference which may be continuously or frequently present at a site.

The frequency and level of any such interfering signals should, if possible, be measured in accordance with the EBU impairment scale (see below) and should not give rise to a subjective picture impairment of worse than Grade 2 (just perceptible.)

In our experience interference from ignition, radar or private user's radio transmissions, switching transients
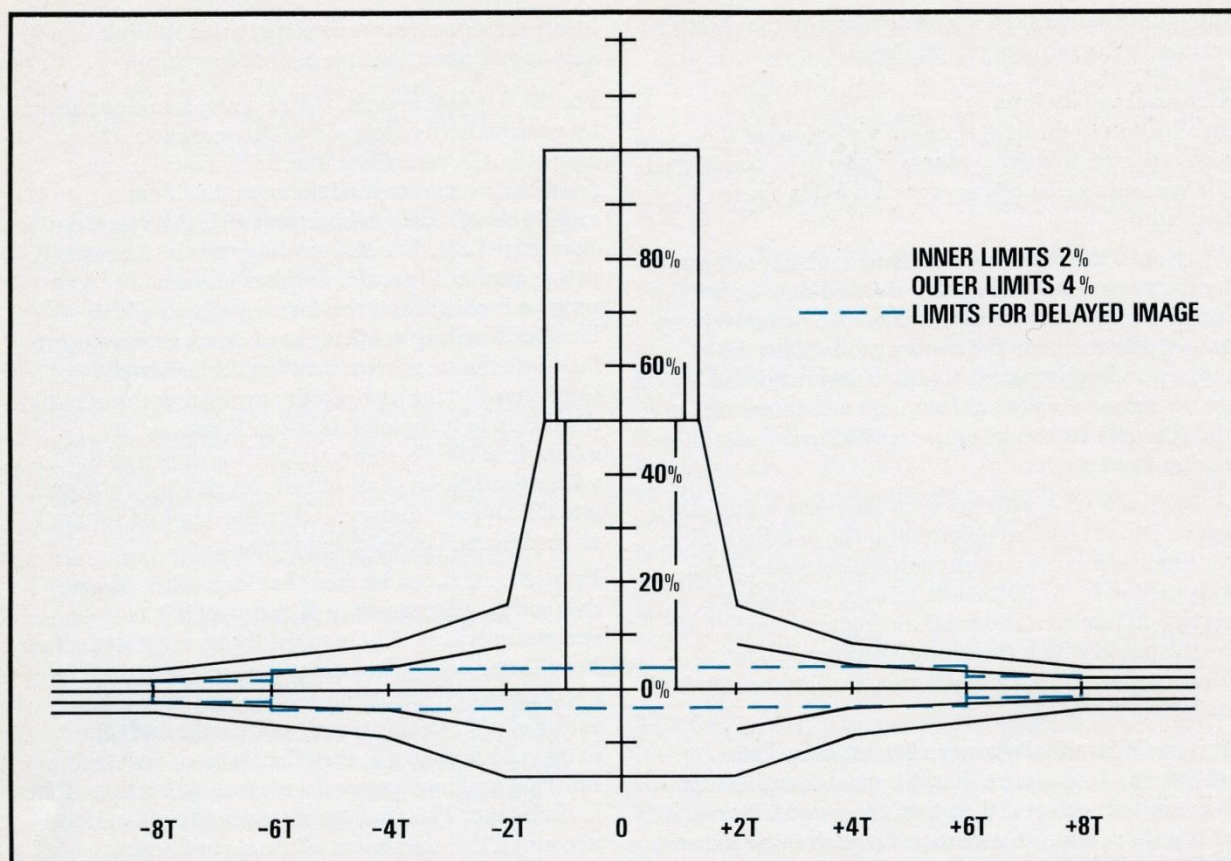
Fig.21. 'K' rating graticule with additional amplitude levels (shown dotted) at $3\frac{1}{2}\%$ from $-6T$ to $+6T$ and at 2% outside this range. For a system in which the echo, of a 2T pulse, is delayed by $0.8\ \mu S$ or more the equivalent 'K' rating is numerically equal to the percentage amplitude of the echo. For the 625-line System I, $0.1\ \mu s = 1\,T$

on power lines, etc. does not generally prove to be much of a problem at prospective relay sites. However, in cases where high power grid lines are adjacent to a proposed site careful consideration has to be given to possible impairments such as delayed images or shadow effects caused by the steel towers and field measurements must be taken accordingly.

The most common form of interference is likely to be from co-channel television transmissions; these could be of varying duration and magnitude depending on distance, intervening terrain, radiated power and receiving aerial discrimination.

In a paper comparing the standards used to plan UHF and VHF networks, Sandell[27] outlines the problems associated with co-channel interference. The implications in areas requiring a large number of relays in close proximity may be seen in Fig.22 which shows diagramatically the position with regard to the relay stations either existing or currently

planned in association with the main UHF station sited at Winter Hill in Lancashire.

The full effect of co-channel interference could only be measured at each prospective relay station by long term field strength recordings, ideally for not less than a year. Detailed assessments of co-channel interference levels at any location are currently made utilizing a digital computer and take into consideration all existing and planned main Band IV and V transmitters on any one channel in the United Kingdom or the Continent as well as the lower power relay stations currently being planned for the further development of services in the United Kingdom.

The method of assessment has been subject to detailed investigation by BBC Research Department,[28] and it is sufficient to note that for any desired location it is possible to obtain the cumulative estimated effect of co-channel interference in terms of interfering field

strength exceeded for a stated percentage of time. By further considering the receiving aerial characteristics, offering possibly directional discrimination as well as that due to orthoganal polarizations, and the protection ratio required based on recommendations used during the EBU Broadcasting Conference,[24] the wanted field strength at the receiving location required to provide adequate protection for 95% or 99% of the time against co-channel interference is computed. This derived value is known as the 'protected field strength' and as a general basis the overall UHF planning in the United Kingdom endeavours to provide that the protected field strength required for domestic receiving locations is not greater than 70 dB/μV/m within the service area of a main station and 80 dB/μV/m for that of a relay station.

It is, therefore, necessary to obtain protected field strength estimates in respect of all re-broadcast receiver (RBR) sites that are to be tested. Where the protected field strength exceeds the value of 80 dB/μV/m or 76 dB/μV/m as appropriate then this value becomes the minimum requirement for acceptability of the site for direct reception and supersedes the limits outlined earlier. In these cases it may be advisable to make a check measurement

Standard Channel Grouping

A	21	24	27	31
B	22	25	28	32
C	23	26	29	33
D	39	42	45	49
E	40	43	46	50
F	41	44	47	51
G	53	57	60	63
H	54	58	61	64
I	55	59	62	65

Non-standard Channel Grouping

D*	42	45	49	52
E*	40	43	46	53
G*	57	60	63	67
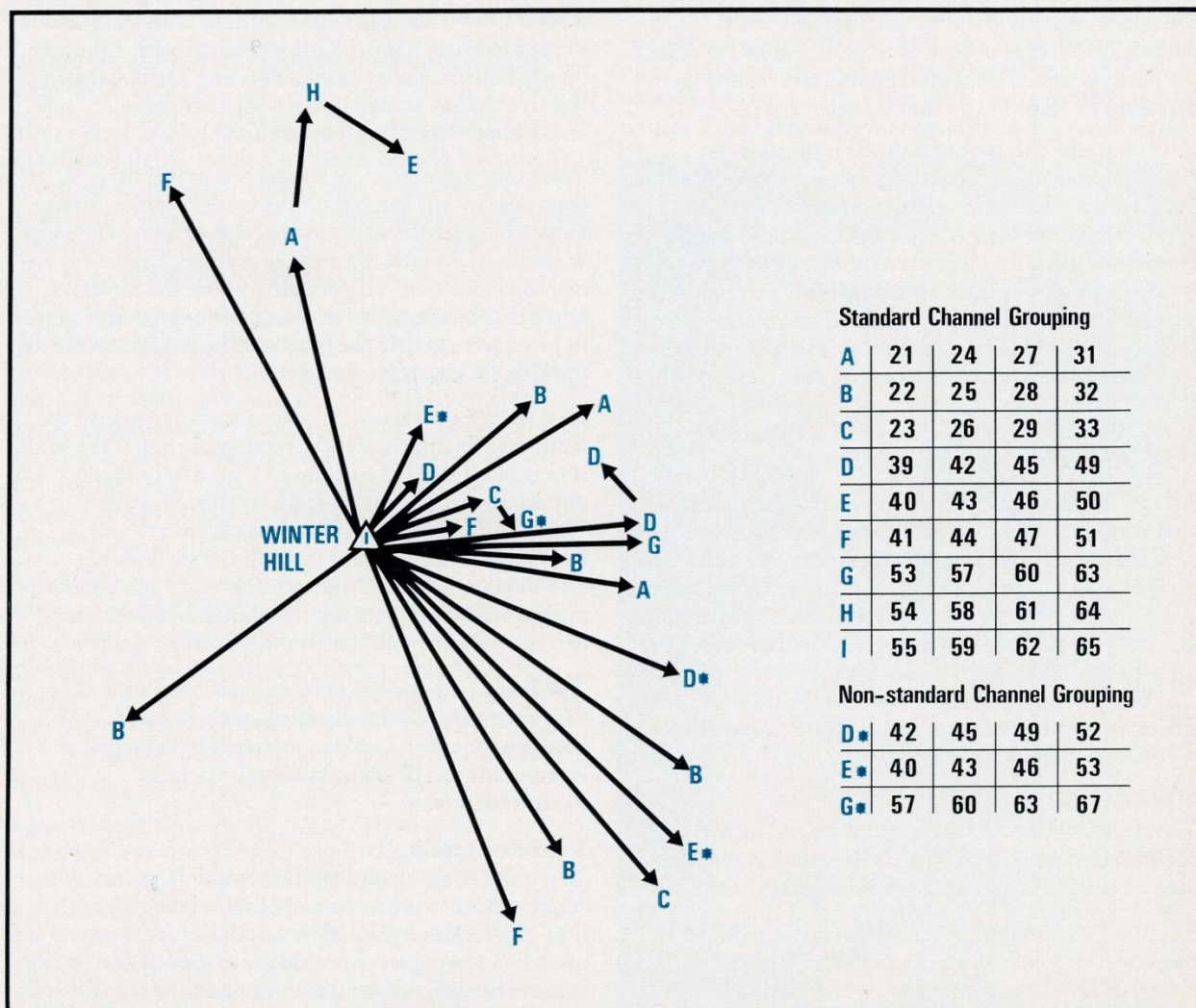
Fig.22. Diagram showing a typical plan for the off-air linking between a main station, in this case Winter Hill in Lancashire, and its relay stations. Note how the channel groupings have been arranged to minimize co-channel interference. This is further assisted by the fact that all main stations are horizontally polarized whereas relay stations all use vertical polarization.

on the signal level which can be received from the principal co-channel interference source.

Site testing

Having determined the basic limits by which an off-air signal could be considered acceptable for re-transmission the next consideration was the methods by which the tests could most readily be performed by the IBA at the probable 200–250 stations which were eventually to be their responsibility.

The ultimate requirement is for mounting receiving aerials at heights of up to 30 metres agl. Since it was anticipated that pilot transmission tests should only be required at a relatively small proportion of sites consideration was given to the possibility of a telescopic mast capable of incorporation in a special purpose vehicle. This would enable test receiving aerials to be raised to 30 metres agl.

Consultation with manufacturers indicated that although masts of suitable proportions were available the physical size of the vehicle required for satisfactory mounting of such a mast was not suited to the requirement for ease of access to as many as possible of the proposed sites. Many of these would be relatively remote hillside or mountainous locations with no established form of access. The alternatives were to restrict the height to 21 metres or to use a 30 metre mast mounted on an independent trailer chassis that could be towed behind the vehicle containing measuring equipment.

This latter proposal was considered to have the advantages of enabling the mast to be transported, located and erected, if necessary, independent of the equipment vehicle. Also, once located, the mast could be left in position whilst the equipment vehicle could be removed overnight for general transport of staff or detachment to other duties that might occur. The obvious disadvantage was that the addition of a trailer would inevitably result in difficulties with regard to access in some locations.

Mast details

The mast is mounted on an extended 'A' frame chassis of overall length 5·75 metres with a single pair of central wheels and a retractable 'jockey' nose wheel.

The mast itself consists of nine telescopic sections ranging from 5 cm to 15 cm diameter with a retracted height of 5·5 metres. When retracted the mast can be cranked and locked in a horizontal position, being pivoted about a point above the basic chassis. There is a detachable 4 metre ladder which

can be placed on the chassis and against the bottom mast section to enable the operator to attach aerials on the retracted mast prior to erection.

Stabilizing and levelling jacks are placed on four corners of the trailer chassis and it is preferable to incorporate a circular level for use during initial site installation rather than relying on visual assessments for levelling.

The aerial feeder cable is fed through eyelets located on the collar at the top of each section and locking rings can be operated manually on consecutive sections during erection if the mast is to remain fully erected at any height over a considerable period. The mast is fully rotatable within its base mounting and a graduated ring has been incorporated with a pointer on the base frame for ease in defining aerial bearing relative to that of the chassis which is normally established once it is set up on a site.

The mast is operated by means of a petrol driven compressor unit located on the trailer chassis, an air valve enabling the operator to raise or lower the mast as required. Whilst the seals between each section are in good condition it is possible to close the air valve and maintain pressure enabling the compressor motor to be closed down if the mast is to be held in an erected position for extensive periods.

Guy rings for attachment of four guys are placed at the top of the final and fifth sections for use if the mast is to remain erected over more than a very short period and for increased stability during windy conditions. A height indicator is also fitted, this basically comprising a thin stranded steel wire attached to the top of the mast, run through locating eyelets and fed on to a spring loaded drum which drives a suitably calibrated mechanical counter.

The height indicator has been positioned so that it can be read by the engineer operating the compressor control valve so that discrete height increments can be obtained for the signal measurements.

Vehicle details

In considering the most suitable vehicle prime requirements were provision of sufficient space for housing the test equipment, suitability for normal road use when towing the mast trailer as well as the ability to traverse difficult terrain under adverse conditions. Obviously, a sturdy vehicle with powerful engine and four wheel drive was a basic necessity whilst the requirement for viewing a colour television
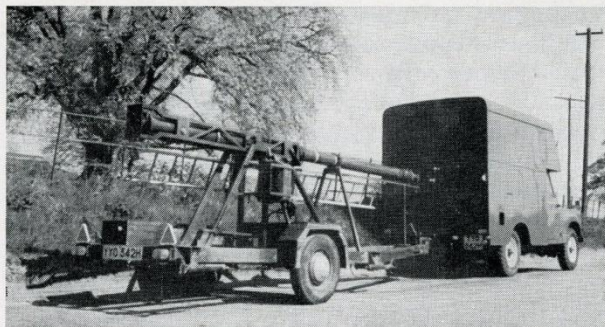
Fig.23. The telescopic mast mounted on its independent trailer, being towed behind the vehicle containing the measuring equipment.

monitor dictated the minimum acceptable internal body dimensions.

After investigating various possibilities the use of a four-wheel drive, three ton chassis vehicle, although affording ample equipment space, was discounted because of its relative size and weight in relation to the constricted access and soft ground surface known to exist at a number of prospective sites.

A long wheel base Landrover cab and chassis with six cylinder petrol engine was obtained and a special purpose body subsequently constructed on the chassis; also a drum winch driven off the vehicle transmission has been fitted on the front of the vehicle for manoeuvering the mast trailer under particularly arduous site or access conditions such as excessively sharp and narrow corners, steep inclines, excessive mud or snow.

A further item for incorporation in the basic vehicle was some method of obtaining a primary power source for operation of the test equipment. The minimum requirements were for a 1·2 kVA, 230V, 50 Hz supply and it was considered that if possible provision should be made for a maximum load of 2 kVA which would allow for supplementary items of test equipment or a soldering iron, etc.

A portable petrol generator was considered preferable to other alternatives in that it would be possible to utilize the generator remote from the vehicle during operation thus releasing valuable space within the vehicle as well as increasing the comfort for operating engineers. Accordingly, provision was made whereby an appropriate generator could be clamped on to a supporting cradle welded on to the trailer chassis. The generator could not be left on the trailer during transportation since it would

upset the carefully designed balance for optimum control and ease of towing and manoeuvering. Furthermore, if provision were to be made within the testing vehicle to enable the generator to be transported, it could be used independently of the 30 metre mast for tests where existing structures could be used for mounting of the receiving aerial.

For transportation, the generator is mounted in a central position immediately behind the front seats. A hinged flap was provided in the nearside of the body such that the generator could be readily withdrawn and transferred to its operating position on the trailer chassis.

A colour television set is included in the required equipment and, owing to the limited size of vehicle body, requisite viewing distance could only be obtained by positioning the set in the rear offside corner to be viewed by an engineer in the nearside
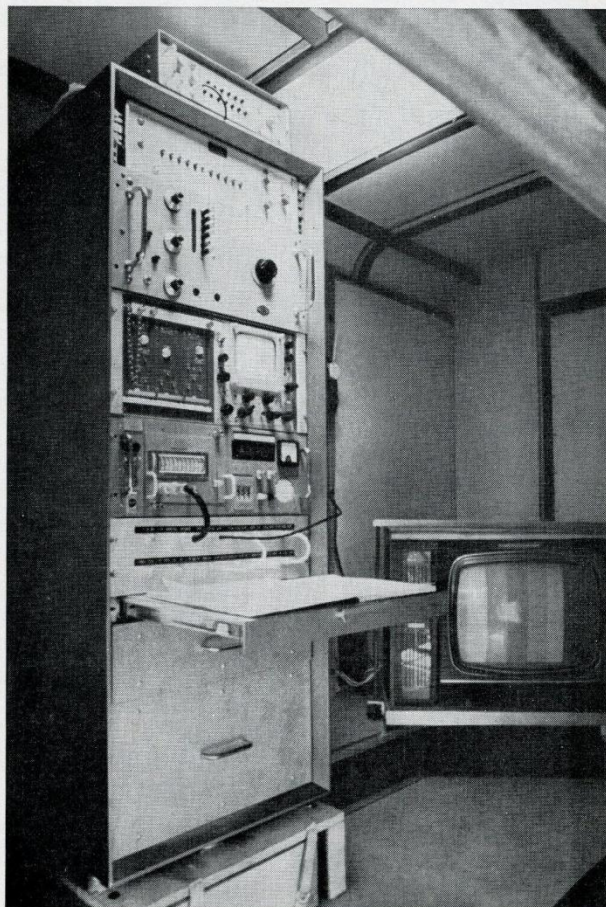
Fig.24. General view of the measuring equipment and colour monitor contained in the IBA survey vehicle.

passenger seat. This was provided with a two position back to permit forward or rearward viewing from the same basic seat position. The set is mounted rigidly to the floor of the vehicle but can be readily re-located along the rear offside of the vehicle for safety during transport, freedom of access through the rear door when loading or unloading equipment, and provision of increased stowage space during transit for lengthy items such as aerials and poles. The set utilized has a screen size of 19in and the viewing distance obtained by this arrangement is approximately five times picture height.

A 19in wide equipment cabinet is mounted against the offside of the interior of the body, immediately behind the driver's seat with the equipment facing across the vehicle. The various items of test equipment specified are of varying sizes and each one is individually mounted on a sliding chassis within the basic cabinet which also incorporates drawers and a sliding desk top section. A smaller equipment cabinet is mounted in the nearside rear corner of the body, principally to accommodate items of test equipment not requiring frequent observation such as a signal level monitor and chart recorder.
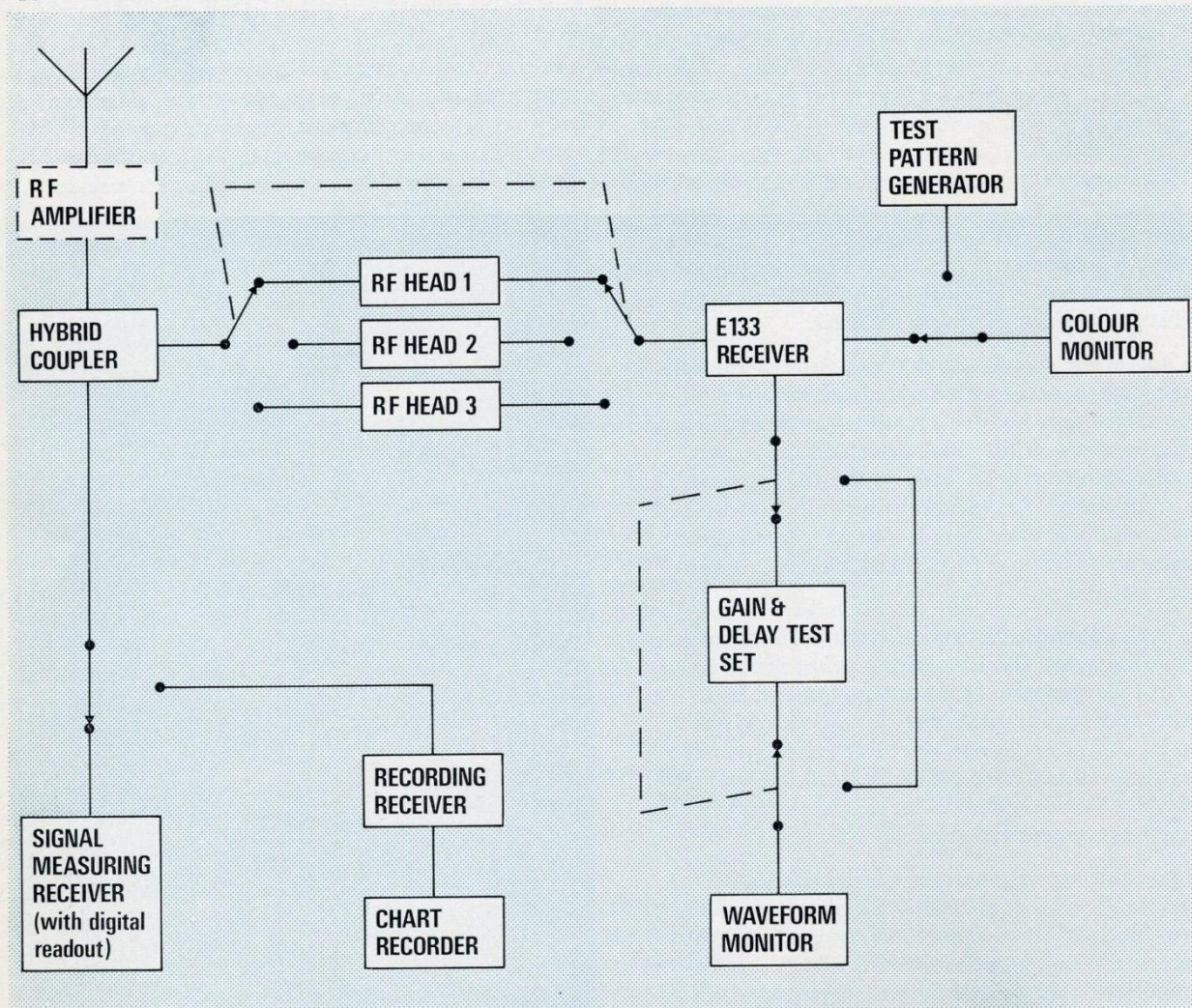
Fig.25. Schematic diagram showing the arrangement of equipment used for carrying out field strength surveys. The signal measuring receiver has digital readout and can be used for determining both sound and vision carrier levels at various aerial heights. A separate receiver and chart recorder are provided for obtaining a continuous record of field strength variations over several hours or days. The video signal is obtained from a third receiver and is available either for subjective assessment on a colour picture monitor or for measurement using a waveform monitor in conjunction with a gain and delay test set.

There is a vehicle tool box located along the nearside of the body between the generator access flap and the rear wheel arch with a seat squab placed over. This, together with a hinged squab located by the generator access flap, forms a couch for the use of engineers during prolonged tests or if stranded on site at any time.

The vehicle and mast design having been determined consideration of detailed provision of requisite test equipment for performing the necessary tests was completed. The final arrangement is shown in the form of a block schematic diagram, Fig.25.

Received signal

A Band IV or Band V skeleton slot receiving aerial is used with 50 Ω coaxial feeder cable whilst a professional grade low-noise amplifier can be incorporated at the mast-head if required. The received signal can be fed through an rf splitter or hybrid to enable independent wideband and narrowband measurements to be made simultaneously.

A UHF field strength measuring receiver incorporating digital readout has been developed by the BBC,[29] primarily for field strength surveys. It is, therefore, featured in the IBA field test vehicle.

The receiver can be used for measurements of both sound and vision carrier levels in order to determine the sound/vision ratio variations with height as well as the absolute vision carrier field strength. There is, as has already been mentioned, an additional need to obtain a continuous record of field strength variations over several hours or days. For this purpose the IBA field test vehicle is equipped with a tuneable UHF station power monitor, initially produced by the BBC, for monitoring the received signal level of a transmission during field strength surveys and tests to give an indication of changes in radiated erp or signal fading. Since only sites at which a high field strength is measured will warrant full investigation there will be sufficient signal available for satisfactory operation of these monitors which have an output for operating a standard chart recorder.

Waveform measurements

The rf signal is to be fed into a high quality re-broadcast UHF receiver developed by the IBA Experimental and Development Department. This equipment was designed primarily for use at main stations requiring their video signal input from off-air programme feeds.

The receiver is of modular construction and has interchangeable crystal-controlled rf modules in respect of each operating channel. It will provide two video outputs, one to feed the colour picture monitor, the other a waveform monitor via a gain and delay test set. The waveform monitor permits individual line scanning, thus the Insertion Test Signals (ITS) can be examined.

A general visual assessment is initially to be made of the ITS waveform response with regard to any serious distortions and inequalities after which the composite 2Tc pulse will be examined in detail for chrominance/luminance gain and delay inequalities. In the absence of gain and delay inequality the base line of the pulse will be flat, Fig.26a, but it is to be expected that the received signal will invariably suffer to varying extents from these inequalities, gain inequality being indicated by the base line of the pulse being curved upwards or downwards whilst delay inequality will have the effect of displacing horizontally the centre of the distorted pulse base line, Fig.26b. In practice a receiver employing an

(a)   (b)
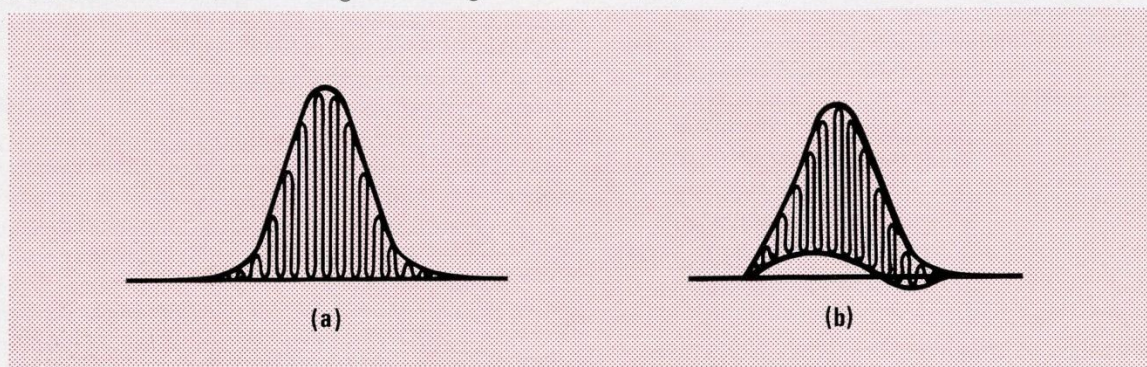
Fig.26. The composite 2 Tc pulse without gain and delay distortion is depicted at (a). If gain inequality is introduced the base line of the pulse will be curved upwards or downwards whilst delay inequality will displace the distorted pulse base line horizontally to the right. Both these distortions are represented together at (b).

envelope detector introduces crosstalk between the luminance and chrominance channels such that even with no propagation distortion the luminance and chrominance components in a 2Tc pulse are reduced by 7% and $4\frac{1}{2}$% respectively. This must be taken into account when making waveform measurements. A measure of these displacements gives an indication of the relative amplitude (positive or negative) and amount of delay (lagging or leading) of the chrominance signal with respect to luminance.

The Marconi Gain and Delay test set employs a nulling technique by which correction is introduced for these inequalities giving a calibrated measurement of chrominance/luminance ratio in dB and delay in nanoseconds. The chrominance/luminance ratio variations can thus be rapidly measured over the full height range and examined to ensure that the limits of acceptance referred to earlier are not exceeded.

In the absence of the gain and delay test set, or if the inequalities are in excess of the capabilities of the instrument which enables chrominance/luminance ratios of ± 3 dB to be measured, it is possible to calculate the inequality from accurate measurements of the 2Tc pulse to which a correction may be applied in respect of luminance crosstalk as measured on the 2Tc bar when chrominance is removed. The remaining test that can be performed with the waveform monitor is to assess the delay and amplitude of delayed signals which, if present, will be seen as images of the 2T pulse. These can be measured in absolute terms to check that they do not exceed the specified limits or, if a quick assessment is required, the 'K' rating graticule can be used.

Picture assessment
Picture quality is assessed using a commercially available 19in colour monitor.
The assessment is made in accordance with the EBU five point quality and six point impairment scales which are as follows:

Quality scale		Impairment scale	
Grade	Description	Grade	Description
1	Excellent	1	Imperceptible
2	Good	2	Just perceptible
3	Fair	3	Definitely perceptible but not disturbing
4	Poor	4	Somewhat objectionable
5	Bad	5	Definitely objectionable
		6	Unusable

It follows that an impairment of Grade 2 or worse requires a simple explanation as to cause, e.g. ghosting, co-channel interference, high frequency patterning, etc.

Additional equipment
The vehicle can also carry a television test pattern generator for use in checking and adjusting the receiver alignment at any time rather than relying on transmitted test patterns, etc. during 'trade tests.' A second UHF station power monitor, as used for recording field strengths, may in some instances be installed at the transmitting station, together with a slow speed chart recorder, if it is required to monitor the transmitted signal level during the test period.

Conclusion
This paper indicates acceptance limits for receiving off-air signals for subsequent re-transmission though it is not intended that they should be considered mandatory.

If reception at a site fulfils all requirements adequately then that relay site may be considered satisfactory for off-air programme feed using an agreed standard receiving system. Conversely, if the site clearly cannot satisfy the required reception standards, then it will be classified accordingly and either the relay station would require re-siting or alternative programme linking would have to be provided.

There may be sites which almost satisfy reception requirements and steps can be taken, by such methods as using more sophisticated receiving equipment or introduction of additional corrective circuits, whereby the necessary requirements may be met.

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PHILIP DARBY, CEng, MIERE, a Northampton man, began his broadcasting career at the BBC where he held several engineering posts. On joining the IBA in 1955 he immediately wrote himself into broadcasting history by completing the log as Senior Shift Engineer on duty at the Croydon station when the first ITV programme went out. Following Croydon, he had spells at IBA stations at Emley Moor and then Dover, where he was Engineer-in-Charge, before being appointed Head of the Authority's Quality Control Section in 1967. He is married and lives in Hampshire.
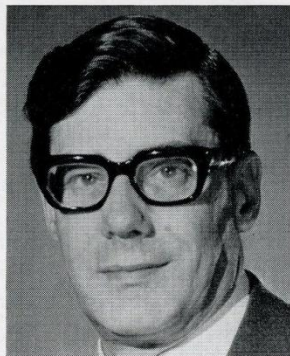
MICHAEL TOOMS, CEng, MIEE, MIERE, joined the IBA in 1967 from ABC Television where his work included early experiments with NTSC colour television. With the IBA he worked for five years as a Senior Quality Control Engineer under Philip Darby, and during this time has served on two CCIR Working Parties. He is now Chief Engineer (Broadcasting) for Rediffusion Hong Kong.
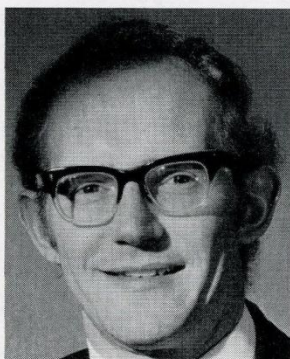
Colour Television Studio Performance Measurements

**by P J Darby
and M S Tooms**

Synopsis

To ensure that the studio centres of Independent Television maintain the highest standards of technical performance, the IBA has introduced a Code of Practice. This Code was formulated during 1967 and lays down tolerance limits for signal paths and picture origination equipment. The tolerances are intended to act as day-to-day targets. Measurements, using CCIR recommended methods as far as possible, are carried out with the installation in its operational mode. The Code of Practice will be given in full in Volume 2 of this series.

The regional structure of Independent Television is such that the studio centres, located throughout the United Kingdom, are owned and operated by 15 different companies. Since these companies are all financed by advertising revenues yet serve areas ranging from major urban conurbations to populations of far lower density, it is inevitable that the studios and facilities vary enormously in size and complexity.

The responsibility for the technical quality of all Independent Television broadcasting rests with the IBA. Clearly, it is a matter of primary importance to ensure that the highest technical standards should be maintained throughout the network. Provided that the companies with the more limited resources produce proportionally less original programme material, there is no reason why any programme contractor should fail to comply with the highest standards of technical performance. To this end, the Authority has produced a Code of Practice which lays down tolerance limits and operational standards which must be observed by every programme company. This code provides the studio planner with a specification upon which to base his design. At the same time, since the specified limits should be aimed for on a day-to-day basis, it provides a set of performance targets for the operational engineers.

The Code of Practice is divided into two parts. Part A is concerned with the performance of the source equipment and that of the studio complex as a whole, while Part B deals with operational practices. Part A is divided into four sections:

1. Definitions and notes (modes of operation and test methods)
2. Video signal paths
3. Video signal sources
4. Audio signal paths.

Modes of studio operation

It is obviously impracticable to make test measurements through every possible signal path in a complex studio installation. At the same time, since individual centres have different methods of operation, it is not possible rigidly to define a signal path which would be appropriate to every installation. It was

therefore decided to define standard paths based on two different modes of operation. Tolerance limits could then be related to these paths without the need to specify in detail the equipment incorporated in each.

The structure of the Independent Television network requires that each studio centre should have two principal functions. Firstly, it must originate programmes from its own studios and secondly it must accept programmes from the network and supply

them to the associated regional transmitting stations. These considerations led to the definition of two standard signal paths called respectively the 'worst path' and the 'direct path'.

The worst path must take into account not only the actual routing of the signal during transmission but must also allow for the fact that a large proportion of programmes are in the form of video tape recordings, and additionally, that most of these contain previously recorded inserts. Three different
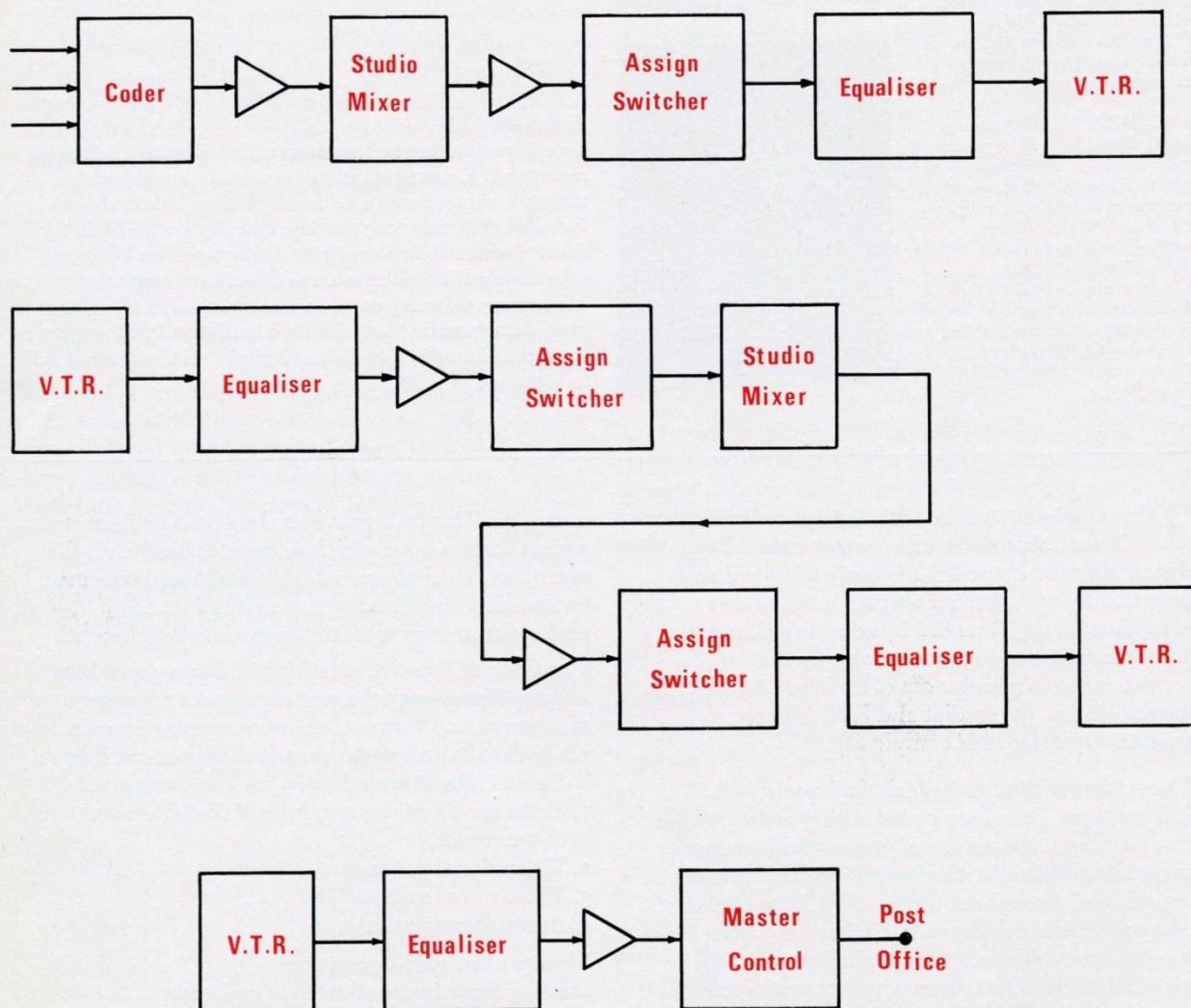
Fig.27. Separate elements of a typical Worst Studio Path. The ITV network is such that each studio centre must be able to originate its own programmes as well as accept programmes from the network and feed them to the IBA's regional transmitting stations for the area concerned. These two cases constitute what is known as the Worst Path and Direct Path respectively. Present day programme origination comprises a large proportion of VTR material which involves recording, editing and transmission processes in tandem. These are separately represented in the diagram.
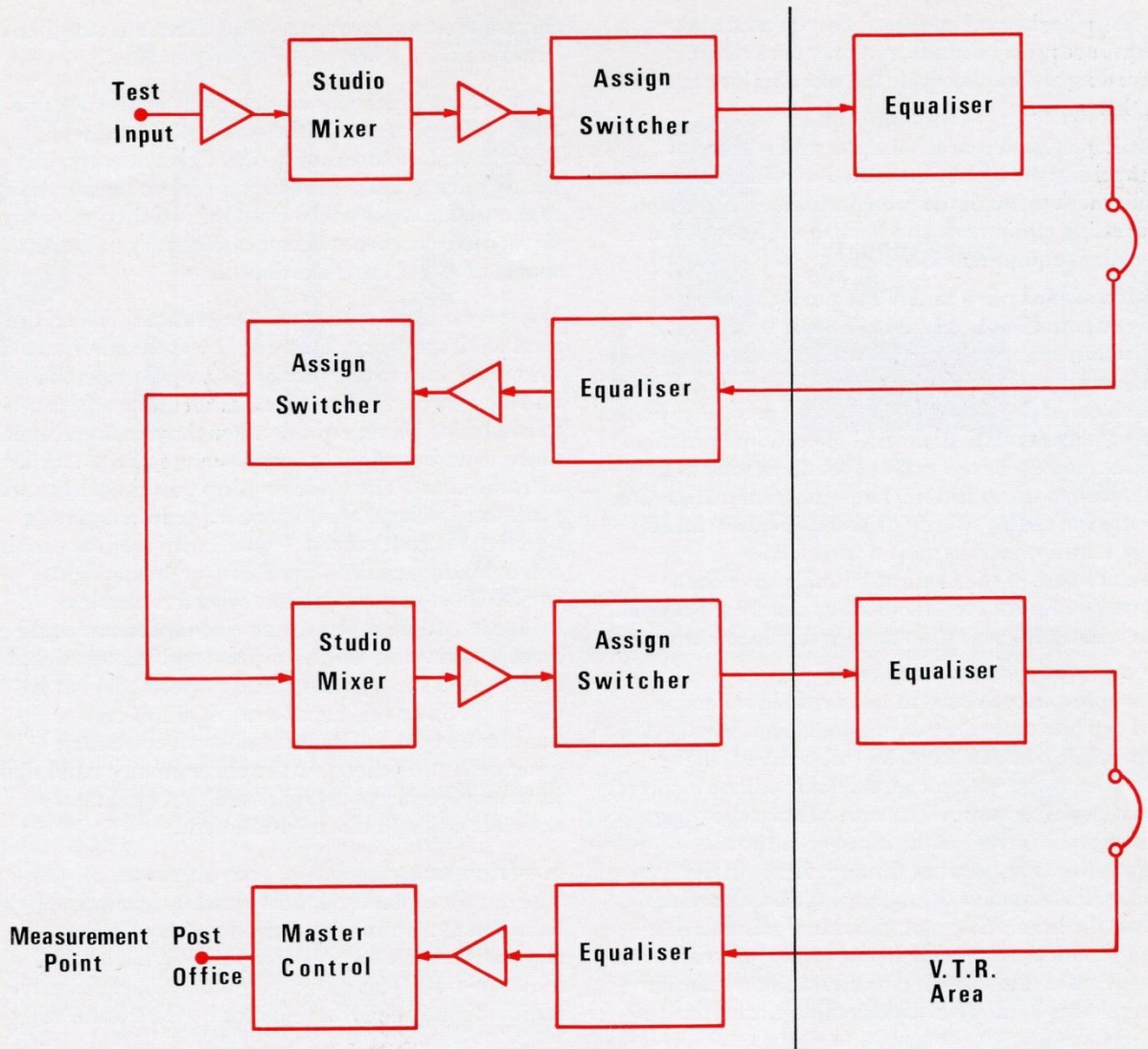
Fig.28. A typical Worst Studio Path. A separate set of performance limits relates to the VTR machine itself and hence, in the practical path shown, the routing in and out of the VTR area is looped straight through. The two sets of performance figures, separately representing the path and the VTR machine, have to be compounded in order to arrive at the overall figure for the system as a whole.

signal paths must be combined in tandem to form a truly representative test route. These paths are illustrated in Fig.27 and accommodate, firstly, the recording of live or film material, secondly, the compilation of the final programme tape and, lastly the transmission of the recording.

When these three paths are combined to form a single configuration a test route is obtained which represents a practical programme path. Fig.28 shows such a combination.

The video tape recorder itself is not included in this worst path and the routing to and from the VTR area is looped. Since the recorder handles encoded signals, it is, in this sense, analogous to a third type of signal path. The Code of Practice, therefore, includes a separate set of performance limits which relate to a single recording and replay cycle. The performance of the recorder must be compounded with that of the worst path to assess the overall limits for the encoded signal. When this exercise is done,

appropriate laws of addition must be used and allowance must be made, not only for a single recording and replay cycle but also, in this case, for a further cycle.

The Direct path is much simpler and is taken as comprising the circuit from the Post Office Terminal equipment through the presentation switching and processing equipment and back to the Post Office Terminal equipment. See Fig.29.

Video signal path and VTR performance

The essential requirements to be met by the test procedure are, firstly, that the measurements must be sufficiently comprehensive to reveal any deficiencies which could degrade the output and, secondly, that the tests must relate to normal operational practice. The circuit under test must be set up exactly as for programme transmission. The CCIR recommendation for routine testing of long distance circuits[30] meets these requirements in most respects. The specifications in the Code of Practice have been related to the CCIR test methods as closely as possible. The measurements fall under ten separate headings:

1. INPUT AND OUTPUT IMPEDANCE

Any impedance mismatch will result in reflection and will also cause incorrect signal level. If an impedance match is frequency dependent, the frequency/attenuation characteristic will be incorrect and signal distortion will occur. Mismatches may arise through errors in the input or output impedance of apparatus, through errors in the transmission lines or through bridged connections across the lines. Although individual mismatches may produce only small effects, studio paths are complicated and often include a number of similar equipments in tandem. Under these circumstances small individual errors may lead to serious cumulative distortion.

Mismatches which exist at any point within a studio path will be revealed in the course of subsequent linear waveform measurements. Consequently, it is the practice to make routine impedance measurements at the station input and output only. Other tests may be made later when it becomes necessary to locate the source of waveform distortion.

It is not satisfactory to specify tolerance limits on the nominal impedance. This would involve laborious bridge measurements through the whole video band and would give no direct indication of the effects of a mismatch on picture quality. For these reasons input and output impedances have been specified in terms of 'return loss'. The Code requires that the maximum peak-to-peak level of any part of a reflected picture signal should not exceed -30 dB with reference to the corresponding peak-to-peak level of the incident signal. The test is carried out using a return loss bridge.[31] Although the whole video spectrum could be explored using only a 2T pulse and bar test signal and a 50 Hz square wave, the 2Tc pulse and bar is also used. Since this signal consists of sub-carrier modulated by a 10T pulse and bar, it contains a great deal more energy in the chrominance band than its monochrome counterpart and thus facilitates accurate and sensitive measurement.

2. OUTPUT SIGNAL LEVEL

The output signal level must be set up accurately before each transmission period and the Code stipulates a peak-to-peak composite signal level of $1 \cdot 0V \pm 0 \cdot 1$ dB. This parameter is one which, ideally, requires continuous surveillance by the transmitting
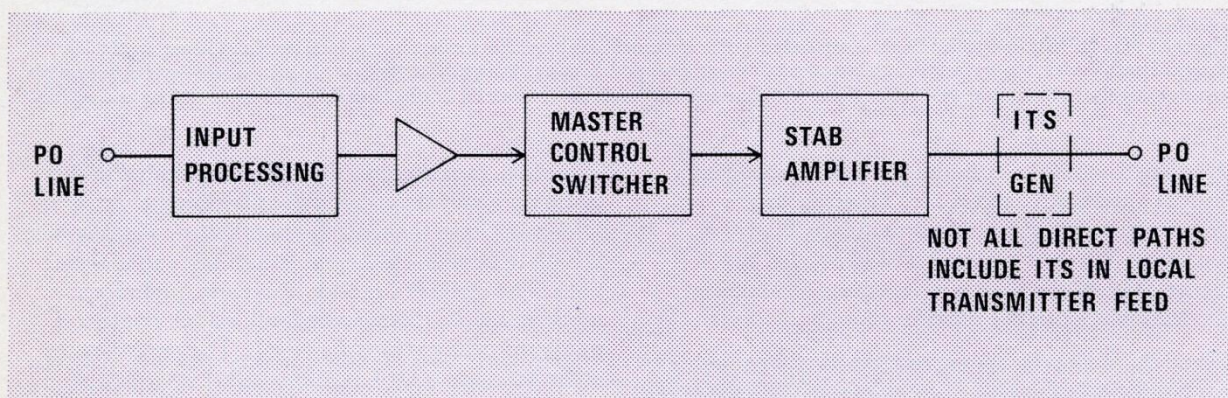
Fig.29. A typical Direct Studio Path. This is applicable to the case when a studio centre is accepting a networked programme, originated by another company, for onward transmission to its regional transmitters.
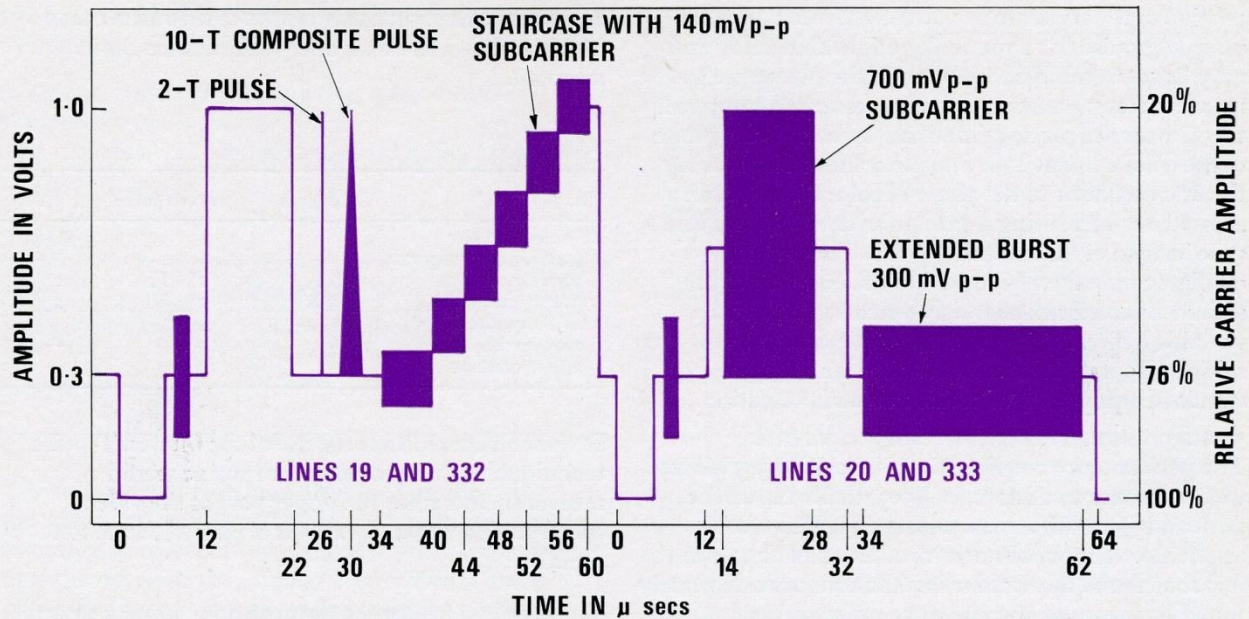
Fig.30. The national Insertion Test Signals (ITS) which occupy two adjacent lines in each field blanking interval. These have now become the accepted 'yardstick' by means of which many of the signal parameters are measured and are usually inserted at or near the signal source. see Fig.31.

station of the individual elements of the composite waveform. Arrangements have been made for all studio centres supplying the network to use insertion test signals as illustrated in Fig.30. At the network input of each studio centre it becomes possible to incorporate automatic error correctors using the insertion test signals as a reference.

It is hoped, eventually, to originate insertion test signals at each individual studio within a complex and at each OB source. A possible system is illustrated in Fig.31. The Master Control area would incorporate an automatic sensor which would allow the passage of incoming insertion test signals. If none were incoming, as would be the case from a telecine source for example, the local signals would be inserted.

3. GAIN STABILITY

Since several hours of programme transmission normally follow the initial line-up stage, the gain stability of studio paths is an important factor. The Code specifies the maximum permissible variation of insertion gain during one hour as ± 0.2 dB for the direct path and ± 0.5 dB for the worst path.

4. NON-LINEARITY DISTORTION

The four separate tests included under this heading together with the associated performance limits are shown in Table 3.

TABLE 3

Test	Direct path	Worst path	VTR
Luminance channel	3%	5%	10%
Differential gain	$\pm 3\%$	$\pm 5\%$	$\pm 7\%$
Total phase errors	$\pm 2°$	$\pm 5°$	$\pm 6°$
Synchronizing signal	$\pm 1\%$	$\pm 2\%$	$\pm 1\%$

The total phase errors are included in the non-linearity tests since they consist of the combined errors, of static and differential phase. Static phase errors, i.e. those which are not level-dependent, may arise at any point where the chrominance sub-carrier is re-inserted (for example some types of studio mixer).

Standard CCIR test methods are used to make all non-linearity measurements but a slight departure from conventional practice is made to derive a figure for static phase error. Differential phase is measured using a signal which contains on every fourth line a five-step staircase with superimposed sub-carrier. The intervening lines are at blanking or white level. The sub-carrier phase on each step is compared with that at blanking level by means of two oscillators. Each oscillator is locked to the phase of the sub-carrier at a time determined by a sampling pulse. The sampling pulses are initiated by an active line selector. One pulse is arranged to coincide with the

portion of the staircase at blanking level. The other sampling pulse has a manually adjustable delay and may be set to coincide with any of the five steps. To measure static phase error it is necessary to compare the sub-carrier phase at blanking level with the phase of the colour burst. This may be achieved by locking the first oscillator to the phase of colour burst, as in a normal decoder, using a gate pulse derived from line sync instead of the sampling pulse. The second oscillator may then be locked to the first step of the staircase waveform, or to any other step, using the variable delay. It is thus possible to measure both static and total phase errors at the same time, using standard equipment with this small modification.

5. FREQUENCY ATTENUATION CHARACTERISTIC

The performance required from 10 kHz to 5·5 MHz, with reference to 1 MHz, is $\pm$0·5 dB for the direct path and $\pm$1·0 dB for the worst path. This test is applicable to monochrome installations only, since it is considered that colour installations are adequately tested by means of chrominance pulse and bar signals.

6. LINEAR WAVEFORM DISTORTION : PICTURE SIGNALS

Table 4 shows the tests and performance limits adopted.

TABLE 4

Test	Direct path	Worst path	VTR
2T pulse and bar (ratio, pulse response, bar response)	$\frac{1}{2}$% K	1% K	2% K
50 Hz square wave	$\frac{1}{2}$% K	1% K	2% K
VLF Response:			
1st overshoot	14%	20%	—
2nd overshoot	7%	10%	—

It was considered that the use of the filtered T-pulse technique was unnecessary for routine studio measurements since the upper part of the video spectrum is assessed by means of chrominance test signals.

The very low frequency tests are done using a square wave of $\frac{1}{3}$ Hz or less. The oscilloscope trace is
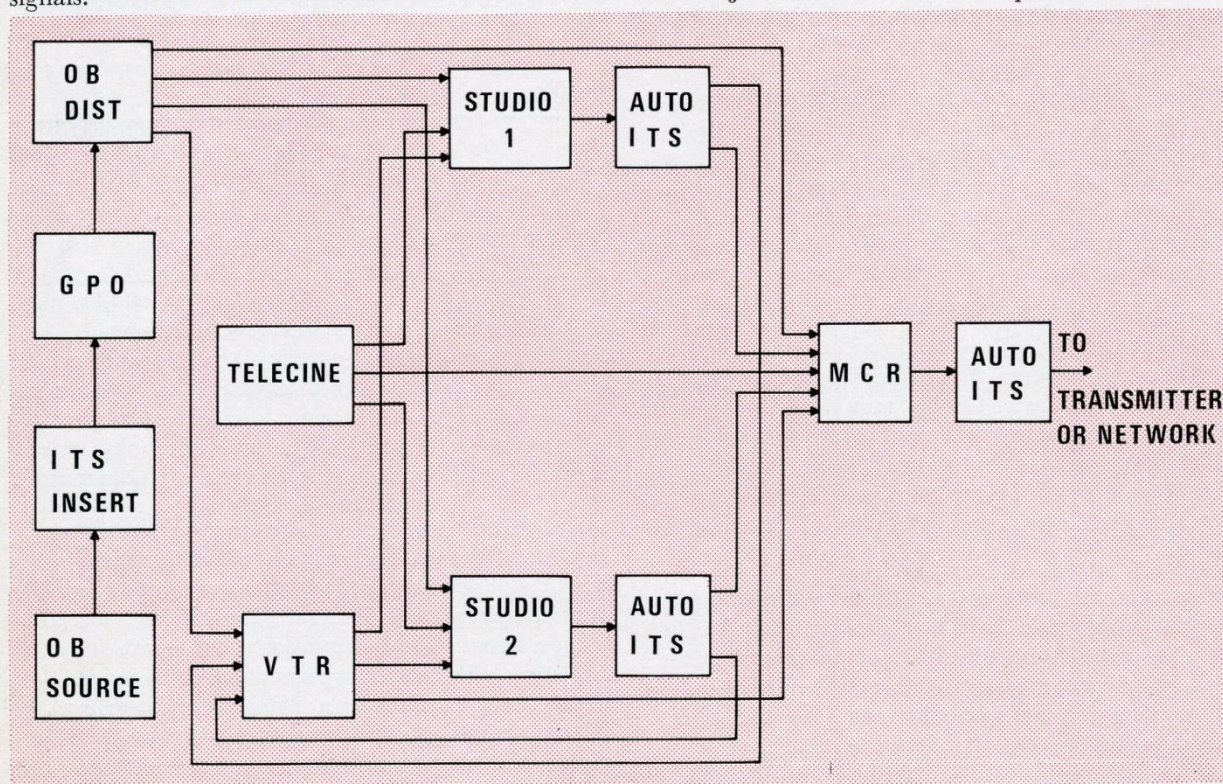
Fig.31. Proposed arrangement for test signal insertion at a studio centre. At the present time the insertion of test signals normally takes place in the Master Control area but ideally ITS should be originated at each studio within a complex and at each OB unit. When these signals are present an automatic sensor would inhibit the MCR insertion equipment but if no such signals were present, as on a direct feed from telecine or VTR, normal operation would be restored.

photographed to facilitate measurement of the overshoots.

7. LINEAR WAVEFORM DISTORTION AND ERRORS: SYNCHRONIZING SIGNALS

The four tests included under this heading are shown in Table 5.

TABLE 5

Test	Direct path	Worst path	VTR
Timings and rise times	To international specifications		
Overshoot	5%	5%	5%
Tilt	5%	5%	5%
Sub-carrier frequency:			
4·433 618 75 MHz	±1 Hz	±1 Hz	±1 Hz

The timings and rise times are based on the CCIR specification for System I[32]. However, an improved tolerance in respect of sync pulse transitions has been introduced, since the existing international limits allow the line sync trailing edge to approach very close to the start of colour burst. The limits have been changed from $0·3 \pm 0·1 \mu s$ to $0·25 \pm 0·05 \mu s$.

A specification for rise time of the colour burst envelope has been introduced since excessively fast transition can lead to transmitter clamping errors. The components of the inserted colour burst should fall entirely within the chrominance band. The envelope rise time resulting from this consideration cannot be precisely defined unless the encoder band-limiting filter characteristics are also tightly specified. For this reason, the transition has been stipulated as 'approximately 400 ns' and no tolerance limits have been included.

8. LUMINANCE/CHROMINANCE INEQUALITIES

Table 6 shows the limits adopted.

TABLE 6

Test	Direct path	Worst path	VTR
Gain inequality	± 3%	± 4%	±6%
Delay inequality	±20 ns	±40 ns	±40 ns

Standard techniques and instruments are used for these tests. It is hoped that the tolerance for VTR delay inequality may shortly be tightened as the result of design improvements.

9. NOISE

The four tests under this heading, including VTR moiré, are shown in Table 7.

TABLE 7

Test	Direct Path	Worst path	VTR
Continuous, random noise, (weighted rms):			
Luminance channel	−64 dB	−58 dB	−52 dB
Chrominance channel	−58 dB	−52 dB	−46 dB
Periodic Noise (excluding VTR moiré)	−52 dB	−50 dB	−52 dB
VTR moiré	—	—	−22 dB

The weighting and band-limiting filters are those recommended by the CCIR.[30] These are incorporated in a new noise meter which has recently been introduced by the IBA's Experimental and Development Department*. This meter has certain special features which will assist studio measurements. such as the ability to measure noise in the presence of line and field syncs, and to measure the noise output from any single head of a VTR machine.

Periodic noise and VTR moiré components may be measured by means of a spectrum analyser. One or more spurious signals within the chrominance band may contribute to the total moiré effect. [33] Since the Code of Practice is concerned with the total effect of such unwanted signals it would not suffice to measure only the largest component present. A method of assessing the combined effect, by using square law addition of the amplitudes of individual components, may be used. Experiments have shown that this method gives a subjectively correct assessment.

A far more convenient method of measuring the total moiré effect makes use of the new noise meter mentioned above. A normal rms noise meter could not be used for this purpose since mean level differences between the outputs of the four VTR heads would be interpreted as a spurious signal. Using the new meter to inspect the output of a decoder from one head only, it is possible to assess the combined moiré effect by direct measurement.

Separate moiré tests are carried out for each primary and each complimentary colour using full amplitude, 100% saturated signals. Using the IBA noise meter the noise level from each of the four heads is measured at the red channel output of a decoder. The reading so obtained must be converted from an rms value to a peak-to-peak figure since the specification relates to a standard picture level of 700 mV p-p. Since the moiré component amplitude is related to the encoded signal allowance must be made for the (R-Y)

See pages 45-54

weighting introduced by the decoder. These two considerations lead to corrections of $+9$ dB and -1 dB respectively, i.e. $+8$ dB. The performance is taken as the maximum level so obtained.

10. CROSS-TALK

Table 8 shows the two specifications which have been adopted as tolerances for cross-talk between studio paths.

TABLE 8

Test	Direct path	Worst path
Interfering signal on all inputs	-50 dB	-44 dB
Interfering signal on one input	-55 dB	-49 dB

The first test involves measuring the signal path output level with the input terminated and a $2Tc$ composite pulse and bar fed to all other inputs. This is a severe test and laborious to set up since there are many alternative inputs. In practice, it is found that the cross-talk increases in a roughly logarithmic manner in proportion to the proximity of the interfering signal to the circuit under test. Thus only the closely adjacent inputs make a significant contribution.

The second test was included to enable a more rapid check to be made. Here, the interfering signal is fed to any input adjacent to the path under test. Since the test is less severe the limits have been tightened accordingly.

The subjective effect of video cross-talk on 625-line PAL signals depends upon the type of signal involved and on the degree of differentiation experienced by the interfering signal. Tests have shown that when cross-talk is proportional to frequency the greatest impairment is due to colour-bar signals becoming significant at a level of -34 dB (measured at sub-carrier frequency). With undistorted cross-talk the worst disturbance is caused by monochrome pulse and bar signals becoming significant at -46 dB.[34]

Video signal sources

The performance of source equipment must be assessed in the operational mode as was the case with signal paths. Before laying down tolerance limits it is necessary therefore to define equipment line-up conditions.

Cameras are set up and correctly exposed as for normal studio use. The test chart or slide is required to produce the same peak illumination, at the same colour temperature, as would be produced by a 60% reflectance neutral surface under normal studio

lighting at the same lens aperture. Gamma correction is set at 0.45 and aperture correction is adjusted for a flat response using a square wave pattern equivalent to 400 lines per picture height.

Telecine machines are set up using a suitable test film. In the case of 35 mm. machines the aperture correction is adjusted as for cameras. With 16 mm. channels the film is unlikely to be modulated to a depth greater than 50% at 400 lines. The optical system will account for a further loss of resolution at this frequency. For these reasons it is normal to align a 16 mm. channel to be flat to 300 lines. In the case of flying-spot machines afterglow correction must be set for optimum response. Gain or light control (whichever is appropriate) is adjusted to give a standard white level output corresponding to a neutral density of 0.35. Gamma correction varies with different equipments in use throughout the network but is required to be within the range 0.4 to 0.25.

Tolerances are specified for the performance of image-orthicon and photo-conductive cameras and for flying-spot and photo-conductive telecine machines. Measurements are made of gain stability, black-and-white shading, resolution, geometric errors, registration, positional hum, line streaking and noise. Certain types of equipment, such as clock scanners, are not required to produce a normal grey scale and the performance requirements may be somewhat relaxed. In such cases the gain stability, geometric errors and noise output are related to a subjective quality grading of two on the six point scale.

Performance limits

Although the tolerance limits are based upon published specifications for professional broadcasting equipment allowance must be made for variations in performance which result from testing under operational conditions. The measurement of telecine noise illustrates the type of problem which arises. Manufacturers normally quote noise figures attainable without gamma correction and without aperture correction. Their specifications do not include the noise contribution from the camera tube.

Since the gamma corrector is to be included allowance must be made for its gain as this might affect the noise output. The gain varies with input level and it would be possible to use a test slide whose density was calculated to produce a gamma corrector input at the particular level where the gain was unity. If this were done inclusion of the gamma corrector would not materially affect the overall noise output.

Unfortunately, the input level corresponding to unity gain depends upon the constrast law of the gamma correction circuits and this may vary between 0·4 and 0·25 with different equipments. If the same line-up conditions are to accommodate all machines it is necessary to establish a light input level such that the change of gain with gamma correction factor will be insignificant. The noise output level will then be modified by a constant amount in all cases dependent upon the gain of the gamma corrector at this critical input level. In the case of the flying-spot machines a further consideration arises since the noise output from a photo-electric cell varies as the square root of the signal current.

Firstly, considering photo-conductive machines:—

Gamma corrector output, $Vc = Vs^\gamma$ (where Vs = input)

$$\text{Incremental gain} = \frac{dVo}{dVs} = \gamma Vs^{(\gamma-1)}$$

For values of gamma between 0·4 and 0·25, the change of incremental gain is calculated to be a minimum when Vs has a value 4·4% of that corresponding to white level, 1·0 V, i.e. $Vs = 0·044$ V. At this input level the gain variation is within 0·3 dB over the range.

Taking $\gamma = 0·4$, Incremental gain $= 0·4 \times 0·044^{-0·6} = 8$ dB

Under these conditions the required noise separation must be 8 dB less than without gamma correction.

To achieve an input of 0·044 V a suitable test slide density must be specified.

White level corresponds to a density of 0·35 and this is equivalent to 44·6% transmission.

To obtain an input of 0·044 V,

$T = 0·44 \times 0·446 = 0·0196$

$$D = \log \frac{1}{T} = \log \frac{1}{0·0196} = 1·7084$$

A slide of neutral density = 1·7 is therefore specified and this can be used for machines having gamma correction within the range quoted.

Consideration must now be given to the question of contrast ratio. Taking the case of a machine designed to operate over the contrast range of 125 to 1 and using a gamma correction factor of 0·3, black level would correspond to a gamma corrector input of 0·008 V. This would produce an output at 23% of white level. If the normal operational practice with such equipment was to allow black level excursions to reach a level of say, 5%, an additional 2 dB of gain must be inserted following the gamma corrector. It would thus be necessary, under these circumstances, to reduce the noise separation by a total of 10 dB when using the 1·7 density test slide.

The noise output of the R-G-B channels is measured over a bandwidth extending to 1·5 MHz. The luminance channel, however, is measured over the full video bandwidth and its noise output is subject to the gain of the aperture correction circuit. As with

(a) With first stage input not tuned.

(b) With first stage input tuned.

(c) With aperture correction in.
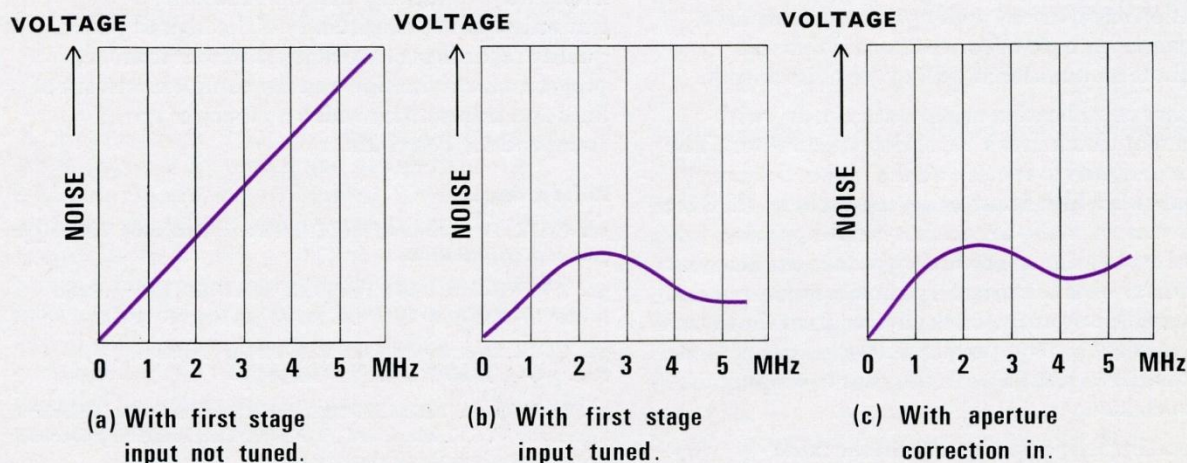
Fig.32. Photo conductive camera noise distribution. Due to capacitive signal loading the 'white' noise generated initially by all photo-conductive camera tubes, as used for colour television, is transformed into a triangular spectrum as at (a). It is therefore a maximum in the region of the subcarrier and so, to reduce this, the first amplifier stage input circuit is usually tuned. The extra gain thereby introduced is later removed and the noise distribution then appears as shown at (b). It is worsened by about 4 dB (unweighted) by the subsequent inclusion of aperture correction. The figure at (c) shows the overall shape of the noise curve.

all photo-conductive cameras 'white' noise is produced initially. Since the signal load is the capacitive input of an amplifier the latter must be given a rising gain/frequency response. The noise from the camera tube, plus that originating in the first stage of the amplifier, is also subject to this rising response. These considerations would lead to a noise distribution at the amplifier output as shown in Fig.32a. To reduce the noise in the region of chrominance sub-carrier the first stage input circuit is usually tuned and the resulting additional gain is removed at a later stage. The noise is then distributed as shown in Fig.32b. This distribution is now further modified by the aperture corrector in the manner shown in Fig.32c. The unweighted noise increase attributable to the use of aperture correction can be computed by comparing the distribution shown in Fig.32c with that of Fig.32b. It is of the order of 4 dB.

This allowance would not be called for in every case since some equipments employ level-dependent aperture correction to overcome the problem of enhanced noise visibility in low-light areas. Provided that the input signal is below the onset level of the aperture corrector no increase in noise ouput will occur.

Having made an allowance of 10 dB for the gamma corrector and a further 4 dB for the aperture corrector, assuming that the latter is not level-dependent, it is still necessary to consider two other factors. The noise contribution from the photo-conductive tube itself will add 1 to 2 dB to the total. The loss of resolution experienced with 35 mm. film requires approximately 2 dB of correction and this will contribute an additional 1 dB to the noise output.

A further complication arises when dealing with equipment which uses a 'level-dependent filter'. The filter is designed to remove all the higher frequency components which occur below a certain level. Since this level is normally above that resulting from a test slide of 1·7 density it is necessary to take the filter out of circuit to obtain a meaningful noise measurement. Although this represents a departure from the normal practise of testing equipment in its operational mode it is considered justifiable in this case to simplify the test procedure.

Considering flying-spot machines the noise performance is normally quoted with reference to a test slide of density 1·0. Since a test slide of density 1·7 is used the reduced light input reduces the noise output from the photo-multiplier. At the same time the additional gain in the gamma corrector tends to

increase the noise output as with photo-conductive equipments.

Noise input to gamma corrector $= K.Vs^{\frac{1}{2}}$ ($K=$ a constant)

As previously, incremental gain $= \gamma Vs^{(\gamma-1)}$

Thus noise output $= \gamma \, Vs^{(\gamma-1)} \times K.Vs^{\frac{1}{2}}$
$$= \gamma K.Vs^{(\gamma-\frac{1}{2})}$$

Taking gamma as 0·4 and considering the specified density of 1·0
(Transmission $= 10\%$):

Noise output $= 0.4K \left(\dfrac{0.1}{0.446}\right)^{-0.1} = 0.4 \, K \times 1.16$

Similarly, using the denser slide ($D = 1.7$ and $T = 0.02$):

Noise output $= 0.4 \, K \left(\dfrac{0.02}{0.446}\right)^{-0.1} = 0.4 \, K + 1.37$

In this case, the output is increased by only 1·4 dB and the inclusion of gamma correction has not directly added a significant amount.

Conclusion

The Code of Practice is the subject of modification about once a year to take account of developments in the art, both of colour television and audio technology. A subsidiary document has now been prepared and issued to specify the standard of performance of outside broadcast equipment including mobile control rooms and radio links.

The results of this surveillance by the IBA in conjunction with other quality control activities, goes a long way to ensuring that the Authority's transmissions are consistently of the highest possible quality regardless of the many different sources of programme origination and the complex network of lines and transmitters which go to make up Independent Television.

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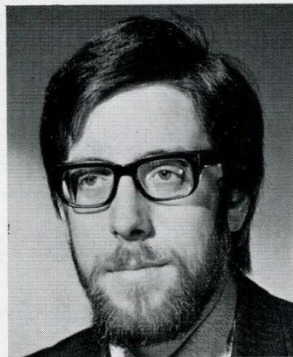
A New Equipment for the Measurement of Video Noise

by F H Wise and D R Brian

Synopsis

A video noise measuring equipment has been developed, for use in television studios and at transmitting stations etc., which fills a long felt need in that its performance is unaffected by the presence of sync pulses. The television waveform to be measured is sampled once during each line period at a position in relation to line sync which can be varied by the operator. In this way the equipment measures the noise appearing in a narrow vertical stripe down the picture. But in order to include the noise, known as 'curtaining noise', which may be correlated line by line as appears on the output of present day line store standards converters, the time delay between the sync and sampling pulses can be made to vary by a regular increment so that the sampling takes place along diagonal stripes, thereby cutting across each of the curtain elements in turn.

The inherent noise level of the instrument is such that accurate rms noise measurements can be made down to about -70 dB (reference $0 \cdot 7$V) and peak-to-peak measurements down to about -60 dB.

Measurement of noise represents an important part of the testing and maintenance of television transmission equipment but a practical difficulty arises in that many items of equipment will operate correctly only when line sync pulses are present. These signals are needed, for example, in receivers for the operation of automatic gain control and in video circuits for dc stabilization. In consequence, it is necessary that any instrument designed for noise measurement be unaffected by the presence of sync pulses.

The noise measuring equipment described satisfies the above requirement and is suitable for use in studios, transmitting stations and in connection with vision links. The operation depends upon a sampling process which has not been previously used in this application and which is shown to give satisfactory results.

Methods of measuring noise in the presence of sync pulses

The equipment is needed for the measurement of noise in 75 ohm circuits at a standard level of 1 V peak-peak (p–p), that is, with $0 \cdot 3$ V sync pulses. It is customary to express noise level in dB with respect to the picture amplitude ($0 \cdot 7$ V) and this is normally measured as a p–p quantity for low frequency (power supply) noise and as an rms quantity for wide bandwidth (random) noise. The minimum sensitivity required is about -65 dB for rms and -55 dB for p–p measurements, so that it is clear that some specfic provision must be made to discriminate against sync signals present which are some 40/50 dB greater than

the above levels.

A number of methods have been used to achieve this result:

a The most basic method is by direct assessment of the p–p value from a CRO display. If required, the rms value may be estimated from the p–p value by use of a correction factor.

b By application of a pulse train equal and opposite to the sync pulses so that cancellation occurs.

c By time gating the signal such that the sync pulse information is excluded leaving about 50–80% of the active line time for measurement.

d By frequency separation, making use of the fact that the spectral components of a line sync pulse train are located at integral multiples of line frequency. If measurements are made in the narrow frequency bands between them no sync information is present and only the circuit noise will be detected.

e An extension of the sampling principle in which a single sample is taken of the voltage appearing at one point along each line.

Although in principle extremely simple, method a has a number of disadvantages. First, it is not possible with some types of oscilloscope to employ sufficient gain to observe the noise present without at the same time affecting the display because of overload due to sync pulses. Second, for the measurement of wideband noise, the correction factor used to convert from p–p to rms is arbitrary and depends upon the spectral density of the noise and the definition of p–p. In practice, a factor of about 17 dB is normally used, which, for 'white' noise assumes that p–p is defined as that value exceeded for not more than about 0·05% of time. Experience has shown that different observers can 'measure' the same rms noise level when using this method and obtain results differing by as much as 6 dB. For most purposes this degree of uncertainty is too great and a more accurate technique is needed. Methods b, c and d have been described elsewhere.[35, 36, 37]

For many purposes, method c is satisfactory and several instruments have been put into production which depend upon this principle. The latest application of the method would be to measure noise in the so-called 'quiet line' of the field blanking interval by gating out all information except that occurring in one line.

A practical difficulty occurs with this type of instrument because unless low frequencies are excluded, any line tilt on the measured waveform shows up as noise. In the case of a VHF transmitter operating at white level, a 2% sag across the line due to power supply regulation is not unusual so that during the gated interval, about 1% of tilt will be observed. This sets the minimum measurable level of p–p noise to around −35 dB which is some 20 dB short of requirements.

The frequency separation technique described under d has been used with success but it gives a result which is applicable to one part of the spectrum only. For certain purposes this can be an advantage but is not convenient for operational use.

Primarily for the above reasons a new method of measurement e has been proposed which avoids this difficulty. This is an extension of the well-known sampling principle. A sample is taken in each line but whereas in method c a large amount of noise data is gathered in each gated-on interval, in this method only a single 'instantaneous' value or sample of the
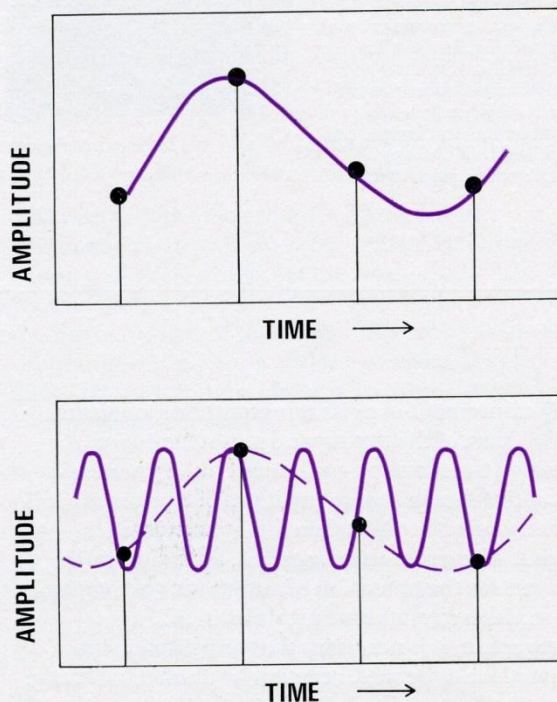
Fig.33. Basic sampling theory. The maximum output frequency of a sampling system is one-half the sampling frequency (fs). In the upper diagram the waveform being sampled is of a frequency less than $fs/2$. However, in the lower figure it is greater than $fs/2$ but the derived output, though of correct amplitude, is reduced in frequency to a value less than $fs/2$.
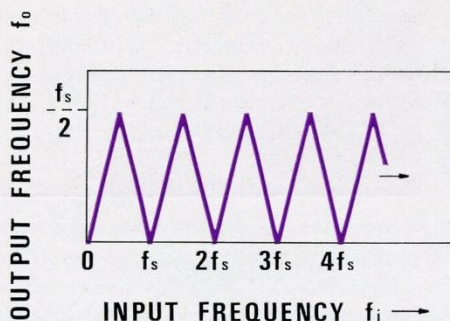
Fig.34. In a sampling system the output frequency f_o, the input frequency f_i and the sampling frequency f_s are related by the expression $f_o = (f_i - N.f_s)$ where N is an integer and $f_o < f_s/2$. This is shown graphically in the diagram.

noise is obtained. Sampling technique is conventionally applied only in cases where the highest frequency to be processed does not exceed one-half of the sampling frequency. In this case we use the sampling technique to process noise in a bandwidth of several hundred times the sampling frequency. The method is believed to be new and is described in detail below.

The method selected

By taking a single sample in each line, noise is effectively measured along a narrow vertical stripe down the television picture.

It is well known that any waveform which contains components up to a frequency f may be described exactly by a train of samples taken at a rate greater than $2f$ and that signals of frequency identical to that of the sampling frequency will not be discerned. For measurement of a television waveform in which sync pulse information has to be excluded, the sampling rate must, therefore, be at an integral multiple of the line repetition frequency and if the sampling rate is set at once per line, then the effects of line tilt or any other variations along the line are eliminated. This does mean that in the case of 625 lines only frequencies up to 7·8 kHz may be retrieved undistorted from the output waveform. If we consider the application of higher frequency signals to the sampling circuits, we see that an output is obtained having the same amplitude but reduced in frequency. This is illustrated in Fig.33.

Consideration of the problem shows that the output frequency f_o is related to the input frequency f_i and the sampling frequency f_s by the formula $f_o =$

$|f_i - N.f_s|$ where N is an integer such that $f_o < f_s/2$. This is shown graphically in Fig.34.

Thus the sampling process compresses high frequency signals into a low frequency ($f_s/2$) bandwidth. For the case where the output from the sampling gate is applied directly to a low-pass filter as in Fig.36, the limit of this process occurs when the sample duration becomes comparable with the period of the input waveform. The transfer function of the process is readily evaluated with reference to Fig.35 which shows the waveform $B \cos \omega t$ sampled at time T over a period S. The mean value M of the waveform during this period S is given by:

$$M = A/S = \frac{B}{S} \int_{T-S/2}^{T+S/2} \cos \omega t, \mathrm{d}T = B \cos \omega t \, \frac{\sin \omega S/2}{\omega S/2}$$

Thus the original amplitude is preserved provided $\dfrac{\sin \omega S/2}{\omega S/2}$ is close to unity, i.e. ωS is small. In fact the error becomes about 10% when the sample period is one-quarter of the period of the input frequency. In order that the response is substantially constant up to 10 MHz, the sample pulse duration should not be greater than 25 ns. The problem has been considered in the time domain but it is also of interest to consider
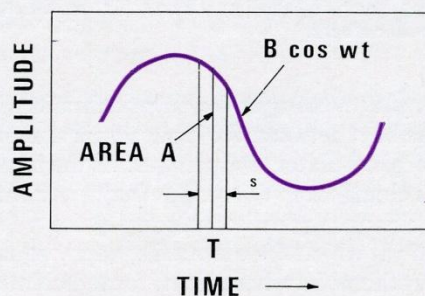
Fig.35. The effect of sampling pulse duration. If a signal of the form $B \cos \omega t$ is sampled by a pulse of time duration S at time t, the output is given by

$$\frac{B}{S} \int_{T-S/2}^{T+S/2} \cos \omega t. \, \mathrm{dt} = B \cos \omega t. \, \frac{\sin \omega S/2}{\omega S/2}$$

Hence the output is the same as the input provided ωS is small. For the response to be substantially constant up to 10 MHz the duration of the sampling pulse should not exceed 25 ns. In fact a 20 ns pulse is used in the practical equipment.

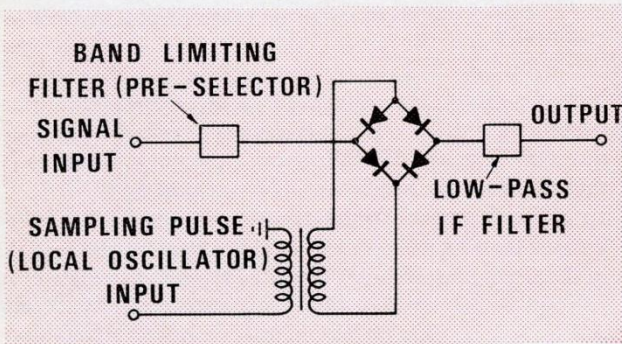the problem in the frequency domain where the sampling system may be regarded as a 'multi-heterodyne' receiver. The receiver analogy is in fact very close as illustrated by the circuit in Fig.36.

The sampling pulse input is in effect a series of local oscillators reproducing the pulse spectrum. If the sampling waveform consists of a train of pulses of duration S and repetition frequency f_s, then Fourier analysis yields the result that the spectrum is as shown in Fig.37. The local oscillator signal, therefore, consists of a series of sine waves spaced in frequency by the sampling rate f_s and of substantially constant amplitude up to the frequency given by $\frac{1}{4}S$. If now the filter following the sampling gate is of the low-pass type, having a cut-off frequency of $f_s/2$ and the subsequent amplifier has a lower frequency limit f_a,
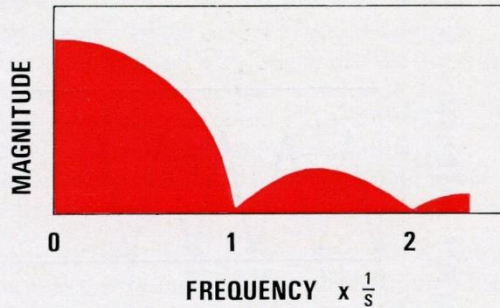
Fig.37. Spectrum of sampling pulse train. A train of sampling pulses of duration S and repetition frequency f_s may be represented, by Fourier analysis, as the frequency spectrum shown here.

Fig.36. The sampling system may also be considered as a problem in the frequency domain by analogy with a basic 'multi-hetero-dyne' receiver shown here.

When this sample and hold technique is used, the sample duration becomes unimportant provided that it remains small compared with the interval between samples and that the system frequency response, from input to the hold capacitor with the gate conducting, is adequate at the highest frequency of interest. It is necessary, however, that the sample gate turn-off time is very short and the criteria for pulse width, given earlier, now apply to gate switch-off time. With this modification, the mathematical relationships remain substantially unchanged and the system still measures along a narrow vertical stripe defined in this case by the turn-off of the sampling gate.

The use of a narrow sampling pulse is of no disadvantage and in fact a 20 ns pulse is used in the practical equipment described later.
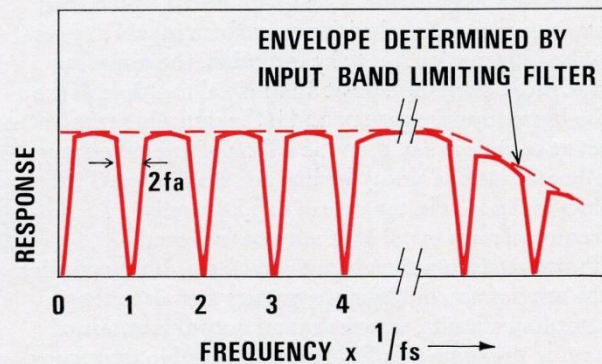
then the signal appearing in the output circuits will be due to the beat between the input signal and only one of the local oscillator components. As the input frequency is changed, so the output frequency changes as shown in Fig.34. Each discontinuity in the characteristic at which the output frequency equals $f_s/2$ occurs at the point where a new local oscillator takes over.

The frequency response of the 'multiheterodyne' receiver becomes as shown in Fig.38.

The arrangement adopted in the practical equipment differs from that described above in that the output from the sampling gate is applied to a hold circuit before passing through the low-pass filter. This causes the input to the filter to be of histogram form rather than a series of narrow pulses and results in a large increase in system gain in the ratio of 20 ns to 64 μs, or about 70 dB.

Fig.38. Frequency response of 'multi-heterodyne' receiver shown in Fig.36. With change of input frequency the output frequency is discontinuous as in Fig.34. The sampling pulse input is effectively a series of local oscillators and at each point where the output frequency equals $f_s/2$ a new local oscillator takes over.

Sensitivity

At first sight it may be thought that by taking measurements during extremely narrow samples of the television waveform, the inherent sensitivity of the equipment would be low. In fact this is not so and is illustrated by the following simplified analysis.

Referring to Fig.39:

S is the effective sampling pulse width, say 20 ns. (The turn-off time for the sample and hold system.)

B is the effective noise bandwidth defined by effective sampling pulse width S and is approx $1/2S$, i.e. 25 MHz.

E_s is the noise voltage to be measured in bandwidth B.

E_g is the noise voltage due to the sampling gate in bandwidth B.

b is the bandwidth of the audio low-pass filter.

E_a is the equivalent input noise voltage of the audio amplifier.

R_s is the source resistance.

R_g is the 'on' resistance of the gate.

Operating conditions are chosen such that the frequency response at capacitor C, measured whilst the gate is conducting, is substantially constant up to an input frequency of 10 MHz and the input impedance of the following amplifier is chosen such that the potential across C remains substantially constant during the interval between sampling pulses. Under these conditions, the transfer function of the sampling gate is unity, i.e. an input of 1 V in the bandwidth B appears at the sampling gate output as a signal of 1 V but in the bandwidth b.

We see that the inherent noise voltage is determined by the root of the sum of squares of E_g and E_a. The value of E_a is about 10 μV rms or 0·7 V rms −97 dB for a mosfet input stage when driven from a capacitive source of 500 pF, while the value of E_g is theoretically about 1 μV rms, assuming an ideal diode gate 'on' resistance of 10 ohms and a noise bandwidth of 25 MHz. Practical semiconductor devices exhibit excess (flicker or $1/f$) noise at low frequencies (within the bandwidth b) which makes the contribution due to E_g some 30/40 dB larger. There is also some contribution to the gate noise E_g from the sample pulse source (which is equivalent to local oscillator noise occurring in a superheterodyne receiver). This is minimized by the use of a sampling gate which is balanced for the sample pulse input. Practical measurements show that E_g is about 30 μV or 0·7 V rms −87 dB.
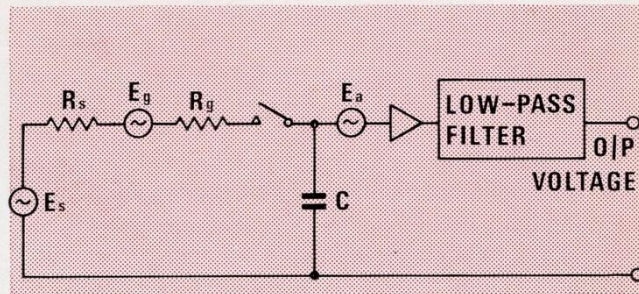
Fig.39. An analysis of the simple equivalent sampling gate circuit illustrated here shows that the inherent sensitivity of the equipment when using extremely narrow sampling pulse widths of 20 ns duration is a lot higher than may at first be thought.

It is seen that E_g is the dominant source of noise limiting the equipment sensitivity. It could be somewhat reduced by using a greater value for S and hence reducing the effective bandwidth B, but this would result in a less good high frequency performance and a less than *pro rata* improvement in residual noise because the excess noise tends to be concentrated towards the low frequency end of the spectrum. The response is substantially uniform across the whole video band but there are 'holes' exhibited at each multiple of the line frequency. The presence of these 'holes' ensures that no response is exhibited to any signal which is repetitive at line rate. If the amplifier following the sampling gate has a response which cuts off at some low frequency f_a, then the 'holes' referred to above each have a width of $2f_a$.

The system provides an output in the audio band which has statistical properties very similar to those of the original signal, with the same rms and p–p value but without any sync pulse information. Because the input bandwidth is not continuous but is of a form shown in Fig.38 some difference exists between the cw sensitivity and the distributed (random noise) sensitivity. This difference amounts to rather less than 1 dB except in the case of cw signals close to an integral multiple of the line frequency.

After conversion into a sync pulse free signal in the audio band, the noise may be amplified and measured using any conventional technique. The concept of rms and p–p is well understood in the case of periodic signals. Where random noise is considered some additional remarks are in order.

If the noise is truly random (white) noise, then the probability P of the peak value having an amplitude

of at least E is given by:

$$P = 1 - \text{erf}\,(E/V\sqrt{2})$$

where V is the rms value and

$$\text{erf}(x) = \frac{1}{\sqrt{\pi}} \int_{0}^{x} e^{-x^2}.dx$$

This is rather more meaningful if shown graphically as in Fig.40.

Oscilloscope brightness is normally set such that p–p measurements correspond to those values exceeded for between $0 \cdot 1\%$ and $0 \cdot 001\%$ of time. This results in a factor p–p/rms of between 16 dB and 19 dB.

The design of the p–p detector in this equipment is such that it responds to values exceeded for about 2% of the time and the resulting factor p–p/rms for random noise is about 13 dB.

Because the rms measurements are made using a thermal device, the readings are not waveform dependent.

Special requirements

A system has been outlined which will measure noise using a sampling method. So far it has only been considered in relation to the measurement of noise in the presence of line sync pulses. It is also required that measurements may be made in the absence of sync pulses or in the presence of both line and field sync pulses (see below under Timing and gating waveforms).

Provision is made for separating the noise into various bands by use of input filters. For the 625-line standard, wideband measurements may be made over the frequency range 40 Hz to 5·5 MHz. For measurements of power supply components a low frequency band 40 Hz to 7·5 kHz may be selected whilst for high frequency measurements, the lf components may be rejected by selection of input filters to give a passband 7·5 kHz to 5·5 MHz. Thus parts of the spectrum may be separated and different sources of noise identified. A different division of the spectrum is useful if it is desired to separate power supply components which may be modulated onto, rather than added to, the television waveform and this requires that components close to all line frequency harmonics are separated. This is achieved by adding a high-pass filter after the sampling gate having a cut-off frequency of about 1 kHz. Figures 34 and 38 show how this achieves the desired result.

It has been shown that the equipment measures noise appearing in a narrow stripe down the television
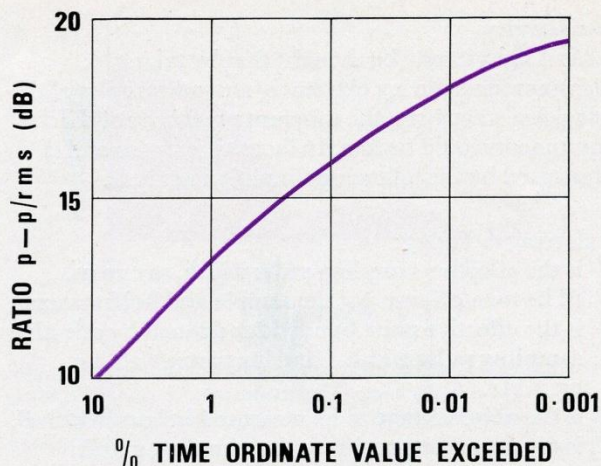
Fig.40. The relationship between p–p and rms noise values depends on the proportion of time that the ordinate being measured is exceeded by peaks of the random noise waveform, as shown in this curve.

picture. This provides an adequate statistical sample of the noise provided that the noise is not correlated line to line. Normally this condition is satisfied except in the case of line store standards converters where so-called curtain noise appears as a series of vertical stripes. In this case the equipment will not detect the curtain noise but will, of course, measure any other non-correlated noise. To overcome this problem the time delay between sync pulse and sample is made to vary so that measurements are made along diagonal stripes thus cutting across each of the curtain elements in turn.

The simplified system block diagram needed to meet these requirements is shown in Fig.41.

Practical circuits

The filters and weighting networks used for noise bandwidth selection and weighting have conventional passive components and the designs were based on existing information.[38] However, due to limited availability of space and the necessity of shielding, some mechanical development was found to be desirable in order to reduce the physical size and minimize pick-up. The former problem was overcome by using a recently available high frequency ferrite for all except the two low-frequency splitter filters, thus reducing the coil size to approximately 1 cm³. The latter problem arises due to the necessity of operating the equipment in strong rf fields, e.g. transmitting stations. Enclosure in a

light gauge tin-plate box formed the rf shielding for each filter and in the case of the 5 kHz and 7·5 kHz splitter filters, mu-metal was used to overcome the additional mains pick-up problem (see below under Low-frequency Amplifier).

The filters, together with a stable sine wave calibration source, are enclosed in a 4in wide ISEP (International Standard Equipment Practice) module which includes the bandwidth and weighting network selection switches and the equipment function switch.

Timing and gating waveforms

The 20 ns sampling pulses are generated in the sampling gate module and the 0·5 μs trigger pulses are generated in the timing unit and timed from the line synchronizing pulses. A line sync separator is used to provide a clean sync waveform, being driven either from the incoming signal or a free running generator of either 10 or 15 kHz nominal frequency, depending upon the line standard selected. This waveform is used to drive a sawtooth generator, the output of which is applied to one input of a fast
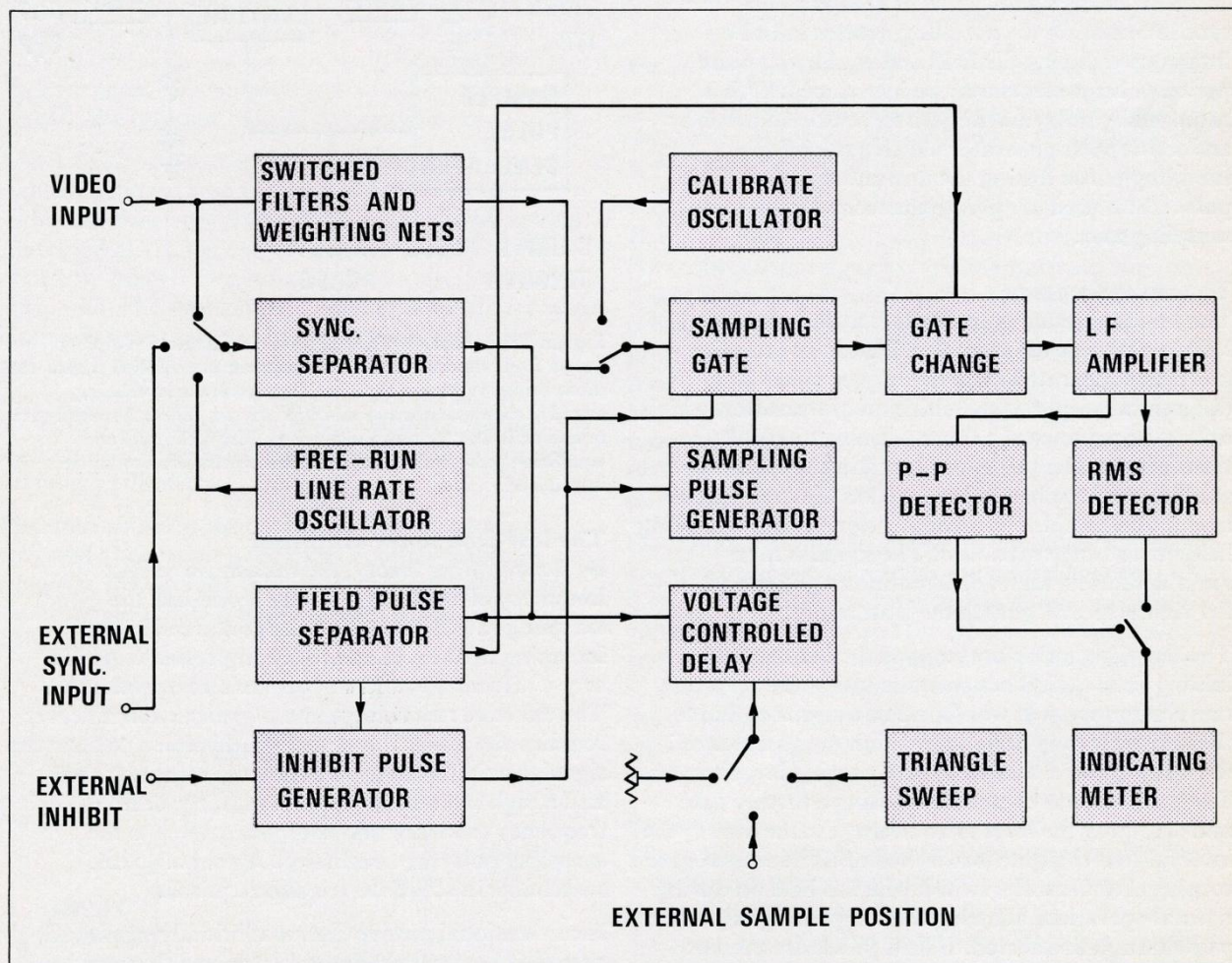
Fig.41. Block diagram of complete video noise measuring equipment. A line sync separator is driven either from the incoming signal or a free running generator of nominal frequency 10 or 15 KHz, depending on whether 405 or 625 line signals are being measured, and its output used to initiate a timing sawtooth. The trigger pulse delay is controlled by a dc level applied to one side of a fast acting differential amplifier. Varying this dc level varies the start of the 20 ns sampling pulse relative to line sync and hence the position of the vertical stripe down which the noise is measured. A 4 Hz triangular waveform can be used in place of the dc which causes the sampling to follow a diagonal track, either side of the vertical stripe, and so to include 'curtain noise', a by-product of the standards convertors in current use, in the measurement. Physically, the equipment is constructed in modular form and measures 19in wide × 7in high × 13½in deep (less case).

differential amplifier. A dc level applied to the other input controls the trigger pulse delay with respect to the sync pulse by an amount proportional to the dc level. Variation of this level, therefore, moves the sampling position along the line, i.e. varies the position of the vertical stripe along which the noise is measured. If a slow (4 Hz) triangular waveform is used in place of the dc level the sampling is effectively swept diagonally back and forth across the vertical stripe enabling 'curtain noise' from a standards converter to be measured.

If the incoming signal contains field as well as line sync information the sampling process must be interrupted during the field and equalizing pulse period or large errors may be introduced. This is achieved by using a field sync separator followed by an inhibit pulse generator which gates off the sampling pulses during the unwanted period. This pulse is also used to operate the second gate in the sampling unit.
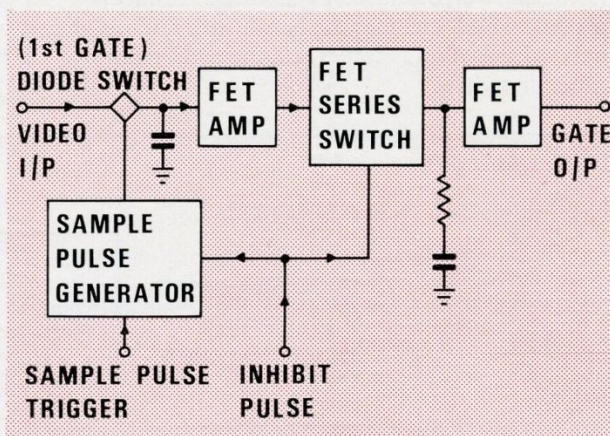
The sampling gate
The basic sampling gate employs a diode bridge, followed by a 20 dB amplifier. The 20 ns sampling pulses are generated from the trigger pulses by a differential amplifier switching an hf transistor, which drives the primary of a three-winding toroidal transformer. The pulses produced in the other two windings are applied in balanced mode to the diode bridge and sample the incoming signal, the level being held on a storage capacitor. The signal is then amplified, using an fet differential amplifier and fed via the second gate to the lf amplifier.

The sampling pulses are stopped during the field inhibit pulse period hence interrupting the sampling process. It was found however that due to the relatively long period for which the gate was off, the sampled level tended to drift causing large errors. The problem was overcome by using a further gate and clamping the level to an average value during the interval that this gate is switched off. The second gate consists of an fet series switch which is held on during normal operation, allowing the sampled signal to pass through unaffected. If field pulses are present on the input waveform, the fet gate is switched off during the field inhibit pulse period thus interrupting any output from the first gate. The level at the output of this second gate is then held at the value stored on an RC time constant, this being approximately the average value over the last field.

Originally, the same inhibit pulse was used to control

both the sampling pulses and the second gate. Due to switching transients it was subsequently found to be desirable to restart the sampling process a few lines before re-opening the second gate and the trailing edge of the second gate inhibit pulse was delayed slightly to achieve this. Figure 42 shows a block diagram of the two gates and their switching circuits.

Fig.42. Block diagram of sampling gates. Balanced sampling pulses from the sample pulse generator are applied across the diode bridge to sample the incoming signal, the level being stored in the capacitor and subsequently amplified. A second gate is used to inhibit the sampling process during the field and equalizing pulse periods otherwise substantial errors may be introduced.

The low-frequency amplifier
By the sampling theory, the maximum output frequency of a sampling system is one-half the sampling rate. Hence the noise contained in the incoming signal is bandwidth compressed to 5 kHz or 7·5 kHz for 405 and 625 operation respectively. The effective rms voltage and p–p excursion however remains the same. It is desirable, therefore, to filter the signal providing a cut-off at half the sampling rate and a high attenuation at the sampling, or line, frequency to ensure that components due to the sampling pulse are eliminated. A gain of 40 dB, switchable in 10 dB steps is also required.

A conventional passive filter was initially employed, preceded by a switched attenuator and followed by a 40 dB amplifier comprising a single linear integrated circuit operational amplifier. This was found quite satisfactory until operated in close proximity to a mains transformer when pick-up became considerable. Because the module was intended for use in an ISEP rack, together with a self-contained power supply, some form of magnetic shielding was essential. The

mains power unit was therefore shielded in mu-metal and the filter replaced by an active system using selective feedback.
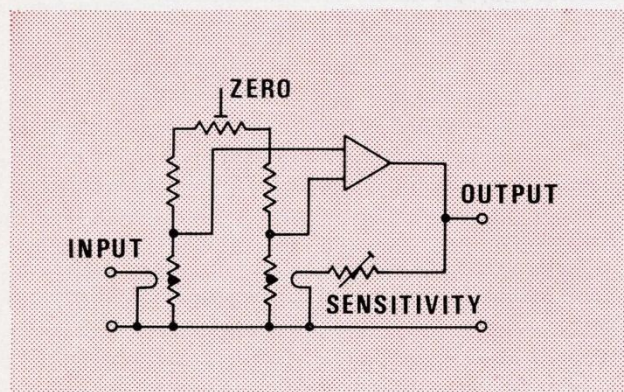
A five-pole Chebyshev filter with 0·1 dB ripple was used, the RC selective feedback components being switchable for dual-standard operation. The system has an overall gain of 40 dB and line rate attenuation of 30 dB.
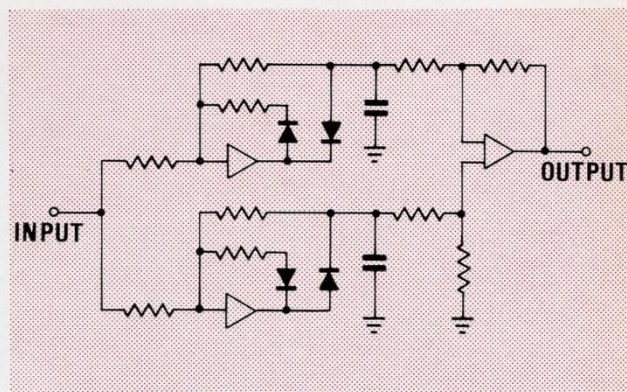
The detectors
For ease of operation a single meter was employed to display both rms and p–p measurements. It was therefore desirable to use an identical decibel scale for both detectors and the law has to be made the same for each. The simplest way to achieve this was to make the response of both detectors linear.

A thermal device is a good choice for rms measurements as true values may be measured without reliance upon some non-linear characteristic. The original arrangement proposed, employed two indirectly-heated thermistors run at constant power dissipation.[39] Unfortunately, the relationship between input voltage and dc feedback although accurately defined, is not linear, so that the alternative arrangement shown in Fig.43 was adopted. This operates in a similar manner but the noise voltage applied to one thermistor is balanced by a dc voltage fed back to the other.

The thermistors in the latter arrangement are not operated at constant power and in order to ensure adequate stability the thermistors are enclosed in an environment which is temperature stabilized within about 5°C.

Fig.44. Basic diagram of the p–p detector. Peak detecting diodes are used in two similar circuits, one operating on the positive peaks and the other on the negative peaks. An unbalanced output is available to be fed, via a selector switch, to the same meter as is used for measuring the rms noise.

In the original design it was ensured that application of excessive input signals could not burn out the thermistors. Experience has shown however that this precaution was insufficient and that additional protection is necessary to limit the maximum input power to well within manufacturers' ratings. In the absence of this additional protection it was found that some drift in the thermistor characteristic occurred making it subsequently impossible to zero the instrument.

Operational amplifiers are again employed to reduce any distortion introduced by the peak detecting diodes. Two similar circuits are used, one operating on the positive peaks and the other on the negative peaks, the resulting balanced output being converted to unbalanced by another operational amplifier and fed to the same meter as for the rms detector via a relay. Figure 44 shows the basic circuit of this detector.

Performance
The inherent noise level of the instrument is such that accurate rms measurements can be made down to about −70 dB (with reference to 0·7 V) and p–p measurements down to about −60 dB. Measurements are normally made on a line repetitive waveform, i.e. one containing line synchronizing pulses and an identical line to line signal. This need not be black level or a white bar but may be, for example, a full test line. Care must be exercised in positioning the sampling pulse if the signal has sharp transients. If the sample pulse were positioned on a sharp rise, any timing jitter in the sample pulse generator would show

Fig.43. Diagram of the rms detector. Two indirectly heated thermistors are used in such a way that noise voltage applied to one is balanced by a dc voltage fed back to the other. To give the necessary stability they are maintained at a constant temperature of 5 deg.C.
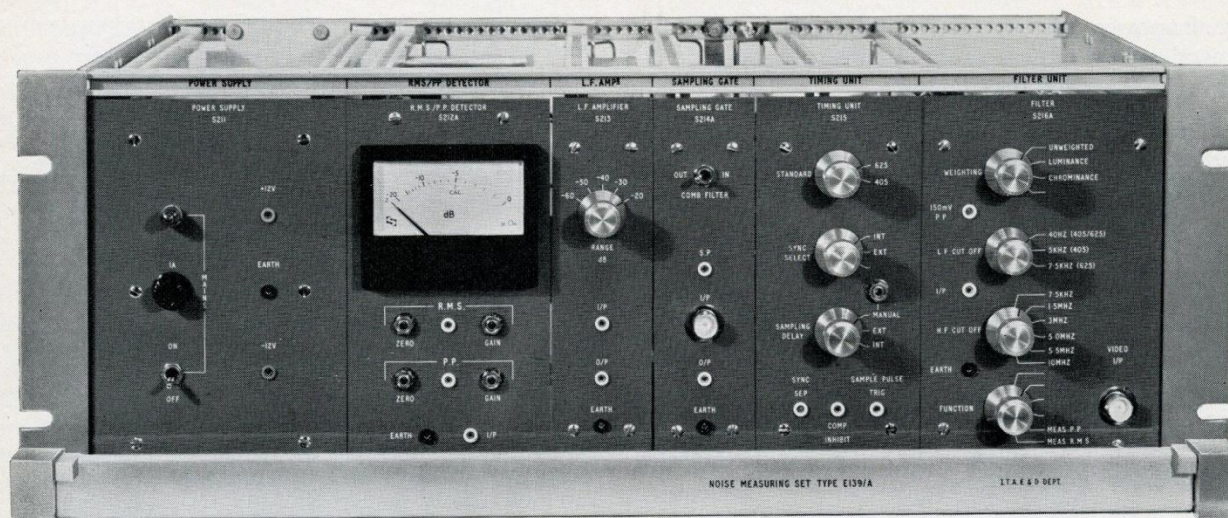
Fig.45. Photograph of the complete equipment.

up as noise. Close monitoring of the sample pulse position is therefore required when dealing with such signals. The advantage, however, is that the noise at any point along a line may be accurately measured and the noise on separate steps of a staircase may be determined. If the incoming signal has no line synchronizing pulses the sample pulses may be triggered from an external sync source or from the internal free-running pulse generator.

The measurement of line-to-line correlated 'curtain noise' from a standards converter has been mentioned (see under Timing and Gating waveforms) but the line information must be constant, preferably at black level, and no low-frequency band limiting filters can be used as these would introduce tilt which would show up as noise in the swept mode.

The presence of a composite signal containing field as well as line sync pulses causes interruption of the sampling process hence causing a drop in the rms sensitivity. This is compensated by the addition of approximately 1 dB of gain, controlled by a logic circuit which senses the presence of field syncs and the selection of 'rms' on the function switch. Peak–peak measurements are unaffected by the inhibit process and no gain change is required. The sampling process may be gated-off by an external signal enabling the noise contribution of individual heads of a video tape recording machine to be measured. The sensitivity reduction must be taken into account and the results weighted accordingly. A switchable active low-pass filter is incorporated after the sampling gate producing a 'comb' filter effect and removing information lying ± 1 kHz from harmonics of line frequency (see under Special Requirements).

A calibration and zero check is provided together with external sync, gating and delay inputs and a remote output from the detector circuits.

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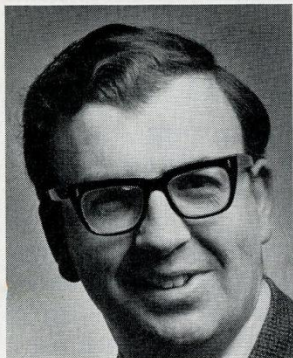
NORMAN GREEN,
MIERE, C ENG,
born and educated in London,
started his career as a Student
Apprentice with EMI. He later
joined the Rank Organization
and worked on the
development of logic circuits
in computers and also the use
of lasers in communications.
Since entering television, first
with ABC and now with
Thames Television, he has
been concerned with viewing
conditions for television and
film, and the application of
digital techniques to television
studio operations.

Computer Aided Programme Presentation

by N W Green

Synopsis

Thames Television has recently constructed a new Studio Centre at Euston, in London. This was primarily intended for the production of topical news programmes and for housing the completely new Presentation and Master Control suite. This complex of signal switching matrices routes the entire company's output to the IBA's transmitters feeding the London area and, via the network, to transmitters in other regions as may be required.

It was decided at an early planning stage that some form of automatic control by means of a computer would offer certain advantages and reduce the risk of switching error. The present article describes the factors which were considered in preparing the equipment specification and the facilities which are now available, but for non-technical reasons the equipment is not yet in service.

The programmes for Independent Television are provided by 15 separate companies in 14 different areas (London having two, one for weekdays and one for weekends) and a news service is provided by Independent Television News. Some programmes are for transmission only within the area local to the originating company, while others are also transmitted in other areas by means of the IBA's network. In addition commercials and programme promotions are always locally inserted and it is because of this complicated build-up of a company's output that the whole network runs to an extremely tight time scale and events have to be decided some weeks in advance. Due to the fact that the timing of network switching is so precise and that commercials are not involved, the Master Control network switching operation can be computer controlled without presenting too much of a problem. The basic networking system is schematically shown in Fig.46. In Presentation Control, i.e. the company's composite programme output to the transmitters for its region, the problem of timing is more acute due to the fact that a cut or fade taken a fraction of a second too early or too late is immediately noticeable and is not pleasing artistically. This is unacceptable in the UK where the standard of presentation has always been very high. It was these factors that led Thames Television to adopt the following principles as a basis for their computerized system:

a that Presentation operations which require the highest degree of sophistication should be executed manually.

b that the computer would aid these operations by pre-selecting the next source to be transmitted.

c that Master Control switching to network would be carried out by the computer on an absolutely accurate time basis.

d that reversion to all-manual operation should be immediately possible at any time.

In preparing the detailed equipment specification the Presentation and network switching operations were observed for some six months and at the end of this time the functional requirements of the system were laid down following discussion with the operational staff. Once these requirements were agreed the problem of translating them into hardware and software was begun.

The system

The programme schedule given in Fig.47 is produced by the Presentation Department and the example shows the normal start of transmission, followed by the schools programmes. The period from 16.16.45 onwards has been deliberately deleted and the programming is picked up again at 17.46.05 to show typical commercial breaks leading to the national
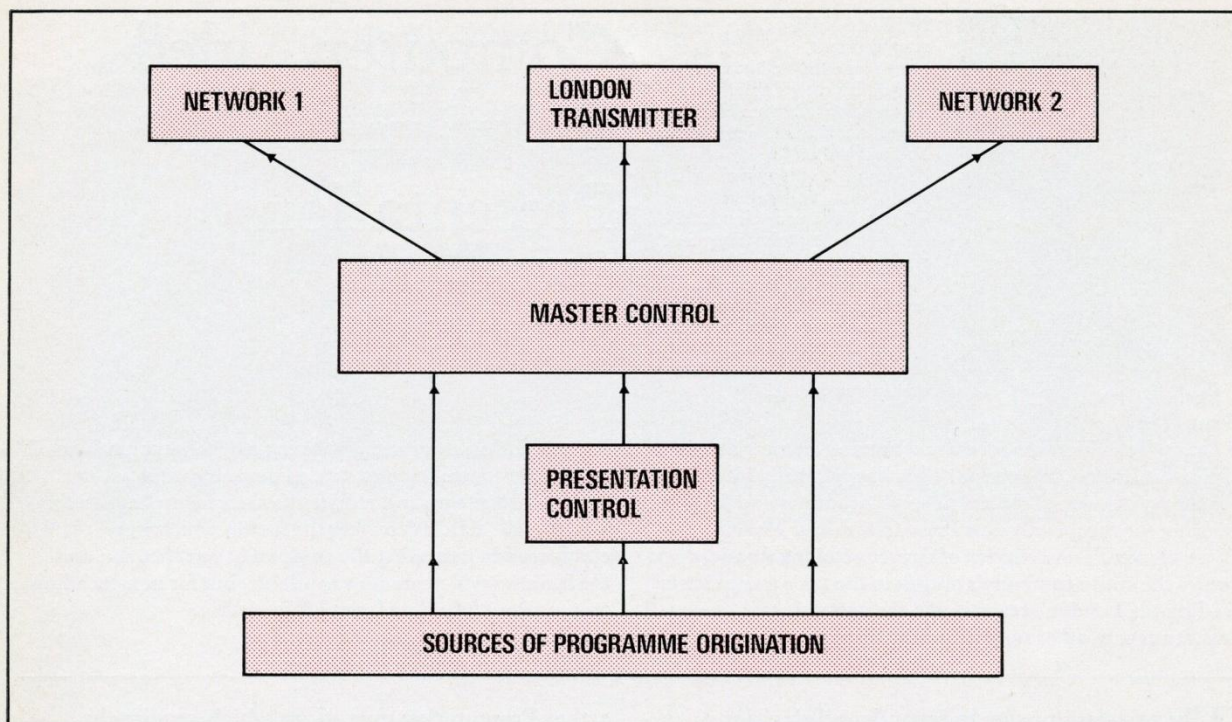
Fig.46. Schematic diagram of the basic networking system. Presentation output is normally fed to the London Transmitters only, while Master Control can provide up to two network feeds as required. On occasions the Presentation output can be fed to either network, via Master Control, to provide special effects such as superimpositions or wipes which cannot be carried out on the Master Control switcher.

news. The first column shows where the programme is being sent to. For example LOC denotes that it is for Thames Television only, ALL indicates that it is being taken by every one of the ITV companies and, if only a few companies are taking the programme, then they are indicated by GRA/ATV etc. meaning Granada, Associated Television and so on. The third column is provided for picture and sound source assignment and is written in by the Transmission Controller of the day who is the executive officer in charge of Presentation. The final column shows the nature of the picture/sound source, i.e. SOF (sound on film) 35 mm, D/H (double head) 16 mm, etc.

Other information is also provided: for example, music titles are given with their identifying numbers, this being for copyright checking. Tape-recording numbers are given in full complete with take numbers and all commercials are described and numbered. It can be seen that this schedule is useful for many functions other than that of Presentation alone e.g. Master Control, the Telecine Department, the Video-Tape Recording Department, logging,

payment of royalties, etc.

The computer does not need to know all this information and it would be expensive and wasteful to store it. Therefore, only that part which is directly relevant to the switching operation is entered into the processor. This is carried out in the orthodox manner by using a teletypewriter for the preparation of a paper tape, and then a high-speed reader feeds the information from the tape into the computer. The format of the computer hard copy derived from the above schedule is shown in Fig.48. The differences are as follows:

deletion of music titles and VTR numbers
deletion of precise network information
abbreviation of programme titles
addition of machine start instructions
addition of automatic machine assignment
indication of machine status.

Before taking a detailed look at the switching system a knowledge of the hardware and its configuration will be helpful.

The hardware

A block diagram of the overall system is shown in Fig.49. The computer uses a 12-bit word length, has 8 000 words of core storage and 32,000 words of disc storage. Mounted on-line to the computer are two teletypewriters which have a printing speed of 10 characters per second, and each are equipped with a paper tape reader/punch facility. One is mounted alongside the computer and is for basic processor operation while the other, situated in the programme loggist's office, is for data entry and programme logging.

In the Master and Presentation control areas are two 1 000 character data display units with keyboard entry (Fig.50); one is used for displaying the switching operations applicable to the network output and the other displays the operations applicable to the Presentation output. These particular display units were especially designed for the project and are of interest for the following reasons:

a it was decided that the output of the data display units should be converted into the form of a standard television signal. It could then be distributed to the various operational areas for use as a visual 'talkback' and in this way personnel could be kept up to date with the switching schedule. For this reason, in preparing the specification for the equipment, work was carried out to find the optimum character size and number of characters that could be read at the recommended EBU viewing distances. This resulted in a display, using the 625-line television format, of 20 lines each of 50 characters and each character occupying 14 television lines in height and the equivalent of 10 lines in width. Hence, at any one time 1 000 characters can be displayed altogether.

Destination	Time	Source	Programme description	Duration	Sound and vision source	
LOC	15.46.01		ITA Caption & Music (On the Brighter Side, Pizzicato Rockalong KPM 1032A)	03.31	Tape	SL
	15.49.32		ITA Annt	00.08	Tape	SL
	15.49.40	T3	Salute to Thames (March) (John Hawksworth)	01.40	SOF	35
	15.51.20		Opening Annt	00.10	AN	AN
	15.51.30		ITV For Schools	01.00	–	SL
LOC	15.52.30	S1	THS Ident (Avoid ABC) Face of the Earth	23.50	VTR/EUS	VTR/EUS
		VTR2	The Windy City VTR/ABC/7409 TK 1. THS Prod. (Avoid ABC)			
	16.16.20		Pub. Annt	00.10	AN	SL
	16.16.30		Promotion	00.15	AN	AN
YTV/THS/GRA SOU/WTV/GPN/ CHA	16.16.45		Diane's Magic Theatre	11.12	YTV	YTV
	17.46.05		Childrens Closing	00.10	AN	AN/SL
	17.46.15	T1	Milk ML 179	00.30	SOF	35
			Ponds Cold Cream (C) 81896	00.30	SOF	35
			Rown Matchmakers 81764T	00.30	SOF	35
			CWS 99 Tea CTS 6	00.30	SOF	35
	17.48.20	S1	Prom	01.35	AN	AN
	17.49.55		Clock	00.05	AN	CL
ITN/ALL THS	17.50.00		News	11.00	ITN	ITN
THS/ALL	18.01.00	T7	Trailer: This Week	00.30	D/H	16

Fig.47. The programme schedule as drawn up by the Presentation Department. The first column indicates whether the programme is being taken by the London Transmitters only (LOC) or being sent via the network to other ITV Companies denoted by YTV/SOU (Yorkshire/Southern) etc. The third column shows how the various telecine, VTR or slide machines have been assigned by the Transmission Controller of the day when it is known which machines are available – hence they are written in by hand. The last column states the nature of the sound/vision source.
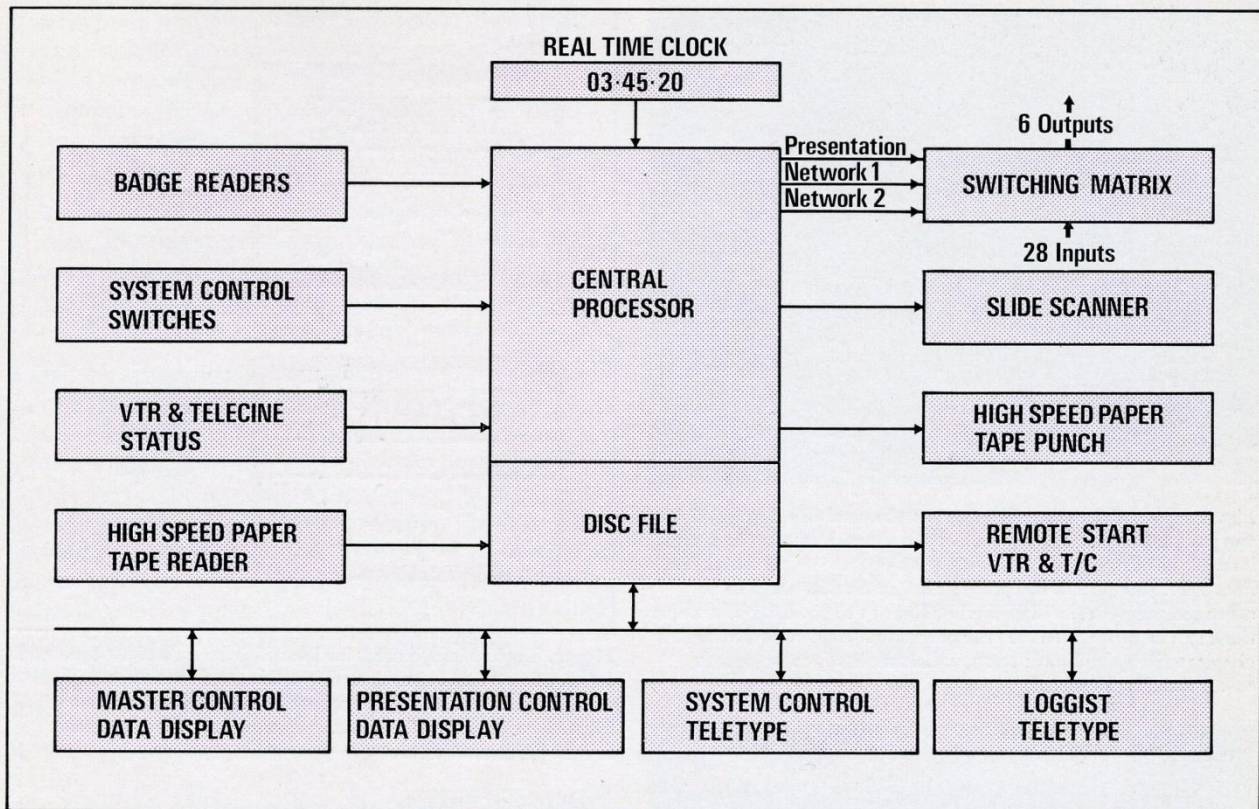
b the display unit has two cursors, a cursor being the point on the data display where the next character will be written. One cursor is under computer control and one under keyboard control. This provides a hardware lock-out of the keyboard in that the computer can control the one cursor over the full 20 lines on the screen, but the keyboard can only operate on the lower 10 lines. It therefore follows that if the transmission controller wishes to amend a programme displayed on the top half of the screen he must first display it on the bottom half, amend it, and then re-insert it into the processor from whence it will be displayed on the top half of the screen. This facility was built-in to prevent accidental changing of programmes near to preview time.

Also on-line to the computer are 12 identity badge card readers, a 24-hour clock, a slide selection interface and, of course, the Master and Presentation control interfaces. An interface is a unit that translates input information of one form into output information of another form. Normally this means converting electrical signals from switches, relays, etc. into codes for entry into the computer or vice-versa. A badge-reader (Fig.51) is mounted on every VTR and telecine machine and its purpose is to read identity cards (Fig.52) on which are punched programme identification numbers. The identity cards are punched in the VTR and Film libraries and travel with the appropriate reel of programme material to the operational areas. The card can be punched with any decimal number between 0 and 999 999. The card reader interfaces are also continually sensing the status of the machines – i.e. whether they are set for local or remote control, whether running or stationary – and feed this information back to the computer. Also routed through these interfaces are the machine 'roll' cues.

The 24-hour interface is fed from the central clock system of the studio centre. It is of interest that a similar clock system is installed at the Teddington studios of Thames Television, some 15 miles from the Euston Centre, and this system is checked and up-dated, if necessary, every hour by pulses sent from the Euston clock. The pulse code which is sent between the two studio centres is in 'binary coded decimal' form and includes parity. Parity is a redundant check digit carried along with the code which is a 1 if the total number of 'ones' in the code is odd or a 0 if the total number of 'ones' is even. This is termed odd parity; even parity uses the reverse

Time	Sound	Vision	Duration	Programme	Network	Source
15.46.Ø1	TP1	SL1	Ø3.31	ITA CAPTION	L	27
15.49.32	TP1	SL2	ØØ.Ø8	ITA ANNT	L	27
15.49.35	TC*	Roll				
15.49.4Ø	TC*	TC*	Ø1.4Ø	SALUTE TO THAMS	L	2ØØØØ1
15.51.2Ø	ANN	ANN	ØØ.1Ø	OPENING ANNT	L	
15.51.3Ø	TP1	SL1	ØØ.59	ITN FOR SCHOOL	L	3Ø
15.52.15	VT*	Roll				
15.52.24	TC*	Roll				
15.52.29	TC*	TC*	ØØ.Ø1	THIS ID OVR ABC	L	2ØØØØ2
15.52.3Ø	VT*	VT*	23.45	FCE OF TH ERTH	L	7234
16.16.1Ø	TP2	CAP	ØØ.Ø5	THIS PRODUCTION	L	1Ø
16.16.2Ø	ANN	SL2	ØØ.1Ø	PUBLICATION AN	L	15
16.16.3Ø	ANN	ANN	ØØ.15	PROMOTION	L	
16.16.45	RM4	RM4	11.12	DIANE MAG THTR	N	
17.46.Ø5	ANN	ANN	ØØ.1Ø	CHILDRENS CLOS	L	
		SL2				
17.46.1Ø	TC*	Roll				
17.46.15	TC*	TC*	Ø2.Ø5	ADDS (DE 11)	L	212667
17.48.20	ANN	ANN	Ø1.4Ø	PROMOTION	L	
17.49.55	ANN	CLK	ØØ.Ø5	CLOCK	L	
17.5Ø.ØØ	ITN	ITN	11.ØØ	NEWS (C)	N	
18.ØØ.55	TC*	Roll				
18.Ø1.ØØ	TC*	TC*	ØØ.3Ø	TRAILER TH WK	N	

Fig.48. So far as the computer is concerned much of the information on the schedule shown in Fig.47 is redundant. That which is relevant is fed into the computer from a high-speed tape reader, the paper tape being prepared by means of a teletypewriter. The figure shows the hard copy.

REAL TIME CLOCK

03·45·20

6 Outputs

Presentation
Network 1
Network 2

SWITCHING MATRIX

28 Inputs

BADGE READERS

SYSTEM CONTROL SWITCHES

VTR & TELECINE STATUS

HIGH SPEED PAPER TAPE READER

CENTRAL PROCESSOR

DISC FILE

SLIDE SCANNER

HIGH SPEED PAPER TAPE PUNCH

REMOTE START VTR & T/C

MASTER CONTROL DATA DISPLAY

PRESENTATION CONTROL DATA DISPLAY

SYSTEM CONTROL TELETYPE

LOGGIST TELETYPE

Fig.49. Block diagram of the overall system. The computer uses a 12-bit word length and has capacity for 8 000 words of core storage and 32 000 words of disc storage. The two teletypewriters have a writing speed of ten characters per second and have paper tape reader/punch facility. A centralized clock system provides a synchronized time reference at both the Teddington and Euston centres. Badge readers are mounted on all telecine and VTR machines, up to 12 in all, and check that the correct programmes have been loaded onto the machines by means of punched programme identity cards.

conditions. By including this digit a check may be kept against the possible occurrence of spurious pulses or the dropping of a pulse from a code. Two sets of pulses are sent every second and these must be the same for action to be taken and the Teddington clock up-dated. The synchronization of the two systems enables personnel in both centres to refer to the same time-scale and permits programmes from Teddington to be dovetailed into the Euston switching schedule at an exactly pre-determined time thus avoiding the need for verbal cues.

The Master Control interfaces select the next source onto the preview bank of the mixer and enable the cutting or fading of that source onto the transmission bank. Information is constantly fed back to the computer as these switching actions are carried out. In the case of the presentation interface the next source on the preview bank of the mixer is automatically selected every time its contents are transferred to the transmission bank. The special

effects switch bank is also preselected onto the preview bank by the interface and information on the operation of all faders and switches is fed back to the computer. Also fed to the computer via these interfaces is information on the setting of the system control switches. These determine which of the following modes of operation have been selected:

a Presentation Control: Automatic Mode (On-time)
b Presentation Control: Semi-Automatic Mode (Off-time)
c Presentation Control: Manual Mode
d Master Control: Manual Mode
e Master Control: Automatic Mode

The interfaces were designed by Thames Television and consist of logic frames containing module cards of the type used in the main processor and are connected by means of some 20,000 wire-wrapped joints.

Fig.50. One of the data display units specially designed for the project. It can display up to 1 000 characters in 20 lines and is fitted with keyboard entry which can operate on the lower ten lines only. Any part of the program schedule that needs to be amended must first be displayed on lines 11 to 20. After alteration these can be re-inserted into the processor. In this way accidental change to items on lines 1 to 10, which are likely to be near to on-air time, is prevented.
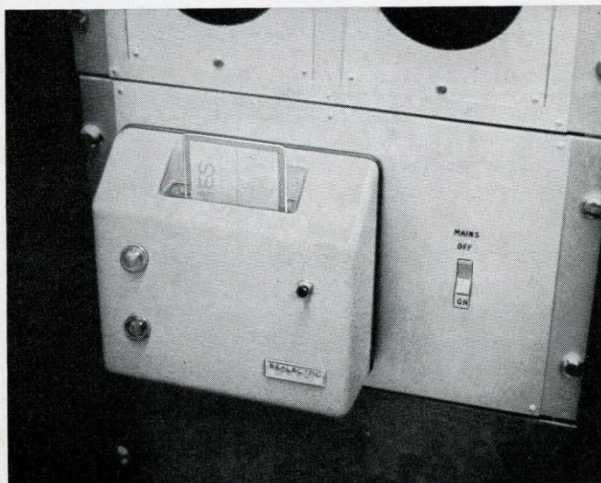
Fig.51. A badge reader with a program identification card partly inserted. One indicator lamp is illuminated when the reader has accepted the information on the card, the other shows that the card has not been properly inserted, e.g. back to front, and the push button is pressed to eject the card. The photograph shows the card in the 'eject' condition.

Overall operation of system

At any time before the day of transmission, the programme schedule is typed out on a teletypewriter and at the same time punched onto paper tape by the high speed reader/punch unit. This information comprises:
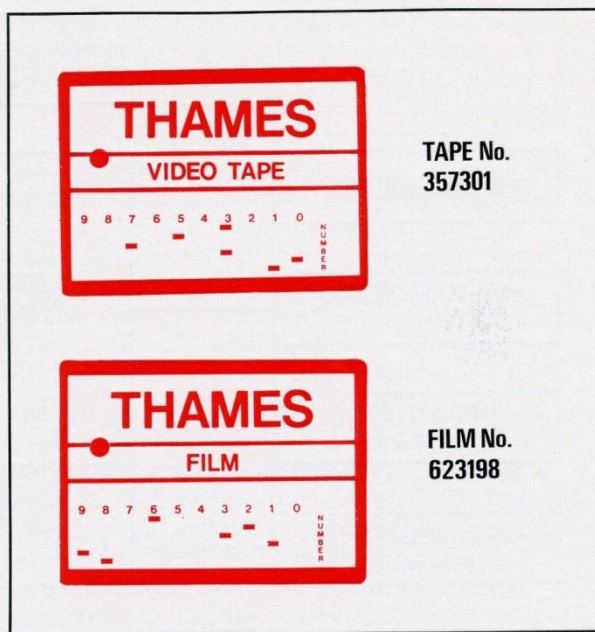
Fig.52. Typical badge cards for identification of a video tape and a film when loaded onto their respective machines. Note the six-digit perforations. Badge cards are punched in the VTR and Film libraries and travel with the appropriate reel of material to the operational areas.

Date of schedule
Time of start of transmission
Duration of programme
Originating source
Programme title
Whether programme is for Presentation, network or both
Type of Item,
    Fixed (F) in time: no opportunity for variation
    Variable (V) in time: opportunity for variation
Film/slide/VTR number.

Once the tape is produced it is kept until the day of transmission when it is fed into the system via the high speed reader. The information is verified as it is read into the computer, i.e. checks are carred out on the date, on the originating sources and that the programme durations check with subsequent start times.

Each input item represents a switching operation which has to be carried out by the computer. As it is validated it is stored away into various files, a file being a collection of related records which are treated as a unit. If an item specifies an input device that requires a 'roll cue' to be generated the following procedure is implemented:

a a list of all input sources is held within the computer and each device which has to be remotely started has a number stored alongside its name. This number is the required run-up time for the device, in seconds, and in the case of a VTR is 15 seconds and a telecine five second.

b having established that a device requires a run-up time, this time interval can then be deducted from the start time of the input item thus arriving at the calculated time which, along with the device name, can be stored as a 'roll cue' item.

Once the schedule has been loaded it can be displayed on the data-displays as shown in Figs. 53 and 54. In the case of the Presentation display the transmission item and the following eight items are normally displayed on the top half of the screen. On the Master Control display five items appertaining to network 1 and three items to network 2 can be seen on the top half of the display. Both displays have the same facilities available on them, and these are called up by typing on the screen certain commands. Apart from being able to amend, insert and delete the computer offers the following facilities:

a display any part of the schedule from a specified time,

b advance the display so that the last item becomes the first followed by subsequent items,

c the nine lines of schedule on the top section of the display can be continued on to the bottom section with a further nine items, the last item on the top half being the first on the bottom half. Carry out duration checks over the whole or any section of the programme schedule so that time errors may be located. If errors are found then the computer writes an unsolicited message on the bottom line of the display stating at what time the error occurs, its length and whether it is an over- or an under-run,

d once the error has been indicated it can be displayed and the duration checked. If the duration is correct and it is a starting or finishing time error then the whole schedule from the time in question can be retimed backwards or forwards,

e if amendments are made but are invalid e.g. a duration of 95 seconds instead of 1 minute 35 seconds, or an unknown source, then the computer indicates there has been an invalid amendment on the bottom line of the display.

The bottom line of the display is also used for indicating unsolicited messages from the badge

Figs. 53 and 54. Photographs taken from the screens of the display units showing 20 lines of program schedule. In the case of the Presentation display (top) the first item shows what is on transmission and the second item is on preview, denoted by the letter P. The R against the telecine roll cue confirms that the appropriate machine has been set to *remote*. As each item is taken on air the time duration figures against that particular item (centre column) count down one second at a time. The letter D on the left of line 11 is the command used for *display* and denotes the first of the lower sequence of ten items selected for display.

On the Master Control display (bottom) the first five items are scheduled for network 1, the next three for network 2.

readers giving warning of a number of possible fault conditions, i.e.

1 that a VTR or telecine machine is not in the remote mode three minutes before transmission,

2 that a badge card has been inserted for an item not forming part of the programme schedule,

3 that a badge card has been inserted with a punching error, i.e. no holes punched in a column, or more than one hole has been punched in a certain column,

4 if the tape or film that has been loaded does not agree with an item on that part of the schedule currently being displayed the machine operator will not see the machine number appear on the data display. The operator can infer, however, that the tape or film number has been located successfully in the schedule because otherwise an error message would be displayed on the screen stating that the number has not been found.

When a telecine or VTR machine has a badge card inserted into its reader the asterisks in the source column on the display change to the appropriate machine number. If for any reason a machine breaks down and the programme material is transferred to another machine, then, as soon as the badge card is inserted in the new reader the display is updated with the latest machine number. The advantage of using badge readers is that the assignment of the different machines to specific programme items need not be decided in advance and is in fact better left until the current situation at a particular time is known.

As soon as a machine is set to 'remote' a letter R comes up alongside the roll cue and subsequently, when the machine is started, the return tally from the machine causes the word ROLL to change to ROLLED. It is possible to program the computer such that if the return tally is not received, a standby slide is automatically selected. In the case of both the Presentation and network data displays a letter P is placed alongside the top item on the display before transmission showing that it is on preview and it is to be noted that no modification is allowed to the preview item within the last three minutes before transmission. When the preview item is taken on transmission the P indicator is moved alongside the 2nd item on the display. Simultaneously with this the programme duration starts to count-down one second at a time.

In operating the network switcher the following procedure is adopted:

a the company identification is normally routed to the output of the switcher,
b three minutes before transmission the relevant programme is switched to preview,
c 30 seconds before transmission the ident signal is faded to black,
d 15 seconds before transmission the programme is faded up onto the transmission busbar.

At the end of the programme:

```
CUT HERE --------------------------------------------------------------

                    THAMES TELEVISION LTD
                    PROGRAMME SCHEDULE

DATE:   26 AUG 70

TX TIME    SND  VIS    DURATION        PROGRAMME      NET     SOURCE

10:52:31   TP1  SL1    03:31           ITA CAPTION    L       000027

10:56:02   TP2  SL1    00:08           ITA ANNT.      L       000027

10:56:05   TC*  ROLL

10:56:10   TC*  TC*    01:40           SALUTE TO THMS L       200001

10:57:50   ANN  ANN    00:10V          OPENING ANNT.  L

10:58:00   RM2  RM2    02:00F          SCHOOL OPENING N

11:00:00   RM1  RM1    15:00F          PICTURE BOX  ) N

11:15:00   RM2  RM2    25:00F          JUST IMAGINE   N

11:40:00   RM1  RM1    20:00F          50 YEARS       N

13:37:31   TP1  SL1    03:31           ITA CAPTION    L       000027

13:41:02   TP2  SL1    00:08           ITA ANNT       L       000027

13:41:05   TC*  ROLL

13:41:10   TC*  TC*    01:40           SALUTE TO THMS L       200001

13:42:50   ANN  ANN    00:10V          OPENING ANNT.  L

13:43:00   RM2  RM2    17:00F          PRIMARY FRENCH N

14:00:00   RM3  RM3    12:00F          MY WORLD       N

14:12:00   RM2  RM2    03:00           INTERVAL       N

                                                      PAGE:   01
```

Figs. 55 and 56. Two forms are available for the hard copy print out from the teletypewriter. The normal close spacing (above) is in the same form as the read out appears on the data display units. The 'photocopy' or wide spacing (below) is more suitable for certain purposes and includes cutting marks indicating A4 sheet size.

```
PRINT 12:00:00 TO 19:00:00

*13:37:31 TP1 SL1   03:31  ITA CAPTION    L 000027
*13:41:02 TP2 SL1   00:08  ITA ANNT       L 000027
*13:41:05 TC* ROLL
*13:41:10 TC* TC*   01:40  SALUTE TO THMS L 200001
*13:42:50 ANN ANN   00:10V OPENING ANNT.  L       1
*13:43:00 RM2 RM2   17:00F PRIMARY FRENCH N
*14:00:00 RM3 RM3   12:00F MY WORLD       N
*14:12:00 RM2 RM2   03:00  INTERVAL       N
*14:15:00 RM1 RM1   15:00  PLACE TO LIVE  N
*14:34:45 VT* ROLL
*14:35:00 VT* VT*   20:00F THE GOLDEN AGE N 400461
*15:46:01 TP1 SL1   03:31  ITA CAPTION    L 000027
*15:49:32 TP2 SL1   00:08  ITA ANNT       L 000027
*15:49:35 TC* ROLL
*15:49:40 TC* TC*   01:40  SALUTE TO THMS L 200001
*15:51:20 ANN ANN   00:10  OPENING ANNT   L
*15:51:30 TP1 SL1   00:59  ITV FOR SCHOOL L 000030
*15:52:15 VT* ROLL
*15:52:24 TC* ROLL
*15:52:29 TC* TC*   00:01V THS ID OVR ABC L 200002
*15:52:30 VT* VT*   23:45  FCE TO TH ERTH L 007236
*16:16:10 TP2 CAP   00:05V THS PRODUCTION L 000010
*16:16:25 ANN ANN   00:20V CHILDRENS OPEN L
*16:16:40 TC* ROLL
*16:16:45 TC* TC*   10:48F PAULUS (C)     B 2::727
*16:27:33 AUX SL1   00:05  FROM THMS (C)  B 000029

*NO SCHEDULE LOADED
```

e the programme signal is maintained for 15 seconds after its scheduled finishing time,
f the output is then faded to black for 15 seconds,
g finally, the ident signal is faded up onto the output busbar.

This complete sequence is automatically generated by the computer for every item on the network schedule.

Instances occur when it is necessary for the network switcher to take the Presentation output for special effects such as super-impositions, or wipes, etc. which are not available on the network matrix. This event is catered for by the network switcher being 'cut' to the Presentation output at the required time but when Presentation switch on to the next item the network switcher automatically reverts to some suitable predetermined source.

Modes of control

Owing to the different situations which may arise during the running of the system various modes of operation are available. These are determined by the setting of the system control switches previously described.

In Master Control items must be switched on time because they are being distributed to other television companies and must fit in with their own detailed schedules. Therefore, only two modes are available:

a Fully Automatic – in this mode programme sources (machines) are started automatically at the predetermined roll times and are automatically switched from preview to transmission,

b Manual – should a programme need to be changed and the schedule cannot be updated in time then it is possible to switch to manual control. The computer can continue to operate and update the display but it is no longer in control of switching and remote starting.

The situation in Presentation Control is different from that in Master Control. Apart from networked items, which must always be on time, it is not absolutely essential for the time schedule to be followed exactly. Therefore, to give the Transmission Controller greater flexibility, the modes of operation are a little more complex. The actual transition from the preview bank to the output is carried out by the vision mixer who takes the next item on the preview bank by operating the 'cut' or 'fade' switches, manually. There are three modes of control:

a Automatic (on time) – in this mode the following conditions apply,
  1 the schedule is followed in every detail,
  2 remote devices are automatically started according to the 'roll' time,
  3 operation of the 'take' switch places the preview item on transmission and the following item on preview,
  4 the screen is rewritten with the start time being the actual time when the transition occurred.

b Semi-automatic (off time) – used when the scheduled time has become out of step with the actual transmission times although, apart from time discrepancy, the schedule is valid. No roll cues are executed unless initiated by the Transmission Controller with the aid of the 'roll' button.

c Manual – in certain circumstances the Transmission Controller needs to have complete manual control, especially when the schedule is not being followed sequentially. When the manual button is operated the computer is disconnected from the switching matrices and merely counts down the current item and stops.

Schedule print-outs

Hard copy print-outs can be made of the complete day's programme schedule, or parts of it. These can be of the schedule currently on display, that which has already been transmitted (historical) or that which has still to go on air.

As Presentation Control does not operate fully automatically the actual transmission times and duration of items can be different from those scheduled. In order to have final log the information on the actual transmission times and their durations are stored in historical records. An accurate log may then be obtained via the teletypewriter and may be in two forms; closely spaced as is the read-out on the data display units (Fig.55) or 'photocopy' which has wide spacing suitable for copying (Fig.56). The 'photocopy' output is also of interest in that cutting marks are automatically generated defining the size of an A4 sheet of paper. The print-out may then be cut up and placed in standard photo-copiers.

Conclusions

The system was completed to the original specification and demonstrated in February 1971. Since then many people who were sceptical of the original concept and wanted only a limited capability from the system have asked for the addition of further facilities. The system design has proved flexible enough to cope with such changes with no more than an alteration to the programme instructions to the computer.

The benefits of computer control when the equipment is finally commissioned should be improved efficiency and switching reliability. It is felt that the system described will serve these ends while providing the means for high-quality presentation.

Recent Technical Developments

SLICE

Source Label Indicating and Coding Equipment has been developed by the IBA to overcome the long-standing problem within the ITV network of programme source identification. The equipment uses lines 16 and 329 in the vertical blanking interval of the 625-line waveform for the transmission of coded data and although there are many uses to which the technique could be applied, programme source identification is the one being initially used by the IBA.

Using the two lines a data signal can be transmitted every 20 ms., for a period of $51.7 \mu s$., allowing each line of data to be transmitted independently of other messages. The various overall requirements of the insertion data system include a good performance at poor signal-to-noise ratios, signal self-timing properties, high security against incorrect message reception and low likelihood of data signal generation from picture or noise. These and other considerations led to the choice of a data format which is partially coherent, self-synchronizing, non-return-to-zero, complemented element transmission at a bit rate of 2.5 M bit per second.

Various error probabilities have been investigated and evaluated, and the system has been tested with different receivers and aerial systems. Among other possible uses of the system are indicating programme categories, transmission destinations and quality ratings, providing a network timing signal, and transmitting instructions and information to various network points.

IP and flashing detector

Initial operational tests on an IP (intermodulation products) and flashing detector for the IBA's unattended UHF transmitters have been successfully completed.

The IBA-developed equipment uses the insertion test signal on lines 20 and 333 of the vertical blanking interval to detect IPs between the vision, chrominance and sound carrier components of the transposer output signal. The 700 mV subcarrier of $14 \mu s$ duration is the portion of the insertion test signal used. The level of IPs measured in this part of the signal is compared with a reference signal derived from the sync pulses of the input signal; if a predetermined level is exceeded for four consecutive 15-second periods an alarm is actuated at the control centre.

The flashing detector, which is linked with the IP detector in a single unit, uses three reference levels to detect black and white flashing in the transposer video output signal. The levels are 10% of carrier amplitude below peak sync, 12% above peak white and 20% of sync amplitude below black level. The latter reference level is used to detect back porch flashing. As with the IP detector, operational safeguards are built into the unit to prevent false alarms by requiring alarm conditions to exist within four consecutive 15-second intervals. Spurious flashes such as noise spikes and those caused by source changes are ignored and the alarm at the control centre is only actuated after at least 30 seconds of flashing.

Film sound dubbing

New advances in film sound dubbing techniques have been made by Scottish Television which considerably speed and simplify the process. In one development, an automatic cuing system provides the dubbing operator, in the theatre, with information on which machine is replaying, and which is coming up, as well as providing a numerical countdown. A travelling light cue is also included for cuing artists and commentators. The machine cues are extended to the mixing desk, illuminating the appropriate channel faders in the correct sequence. Cues are laid down initially by the film editor when he is assembling the tracks; the dubbing cue sheet is thus virtually eliminated, allowing the dubbing operator to concentrate on the artistic side of the master mix.

VTR sound dubbing

Thames Television now operate the Medway sound dubbing system used in conjunction with normal quadruplex VTR machines. This enables separate music, effects and dialogue tracks to be recorded on a multitrack machine for subsequent dubbing, balancing and transfer to the edited videotape.

Kent House

London Weekend Television's new centre, Kent House, on the south bank of the River Thames at Waterloo, was officially opened on 13 June 1972. The centre contains one of the most technically advanced studio complexes in Europe.